**Dissertation on**

# A MORPHOMETRIC STUDY OF MEDIAL MENISCUS OF KNEE JOINT IN HUMAN CADAVERS

***Submitted in partial fulfillment for***

**M.D. DEGREE EXAMINATION**

**BRANCH- XXIII, ANATOMY**

**Upgraded Institute of Anatomy**

**Madras Medical College &**

**Rajiv Gandhi Government General Hospital,**

**Chennai - 600 003**


**THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY**

**CHENNAI – 600 032**

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**APRIL-2017**

# CERTIFICATE

This is to certify that this dissertation entitled

## "A MORPHOMETRIC STUDY OF MEDIAL MENISCUS OF KNEE JOINT IN HUMAN CADAVERS"

is a bonafide record of the research work done by **Dr.S.SARAVANAN**, Post graduate student in the Institute of Anatomy, Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai-03, in partial fulfillment of the regulations laid down by The Tamil Nadu Dr.M.G.R. Medical University for the award of M.D. Degree Branch XXIII-Anatomy, under my guidance and supervision during the academic year from 2014-2017.


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## CERTIFICATE OF APPROVAL

To

Dr.Saravanan.S
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Dear Dr.Saravanan.S

The Institutional Ethics Committee has considered your request and approved your study titled **"MORPHOMETRIC STUDY OF MEDIAL MENISCUS OF KNEE JOINT IN HUMAN CADAVERS"** NO.20032015.

The following members of Ethics Committee were present in the meeting hold on 03.03.2015 conducted at Madras Medical College, Chennai 3

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We approve the proposal to be conducted in its presented form.

The Institutional Ethics Committee expects to be informed about the progress of the study and SAE occurring in the course of the study, any changes in the protocol and patients information/informed consent and asks to be provided a copy of the final report.

Member Secretary – Ethics Committee

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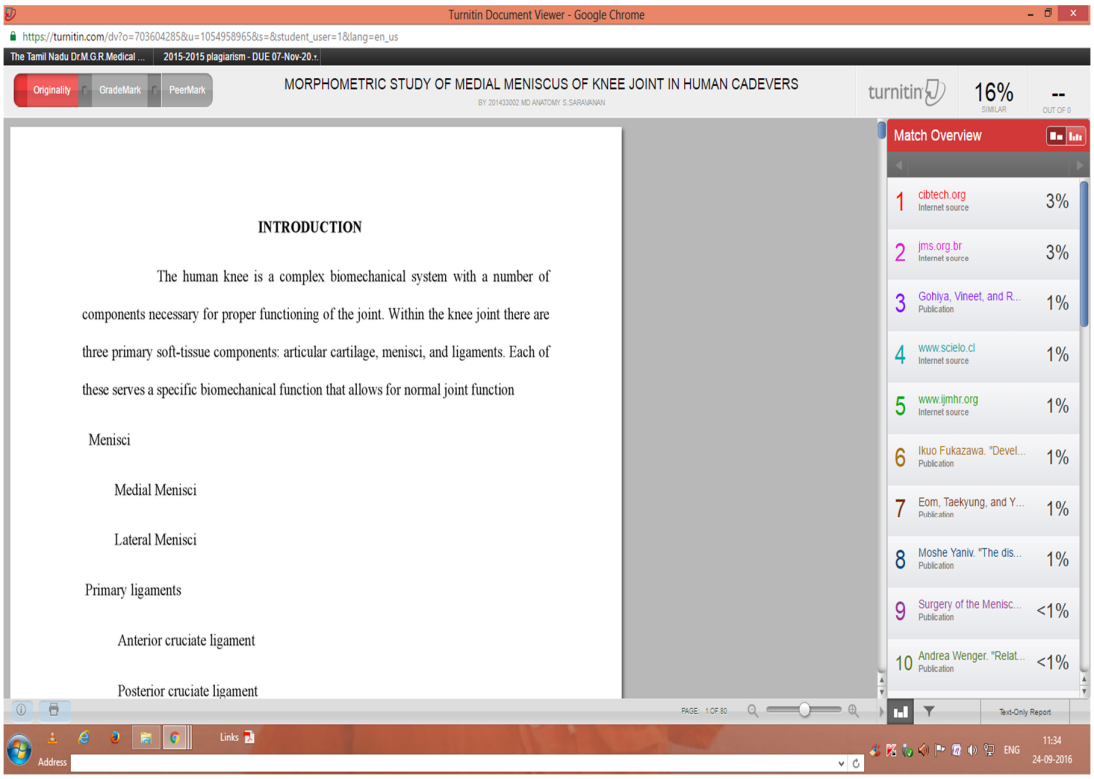
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INTRODUCTION
The human knee is a complex biomechanical system with a number of components necessary for proper functioning of the joint. Within the knee joint there are three primary soft-tissue components: articular cartilage, menisci, and ligaments. Each of these serves a specific biomechanical function that allows for normal joint function
Menisci
Medial Menisci
Lateral Menisci
Primary ligaments
Anterior cruciate ligament
Posterior cruciate ligament
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## LEGEND

| | | |
|---|---|---|
| MM | - | Medial meniscus |
| LM | - | Lateral meniscus |
| OA | - | Osteoarthritis |
| SD | - | Standard deviation |
| UL | - | Upper limb |
| LL | - | Lower limb |
| MTP | - | Medial tibial plateau |
| LTP | - | Lateral tibial plateau |
| ACL | - | Anterior cruciate ligament |
| PCL | - | Posterior cruciate ligament |
| CT | - | Computed tomography |
| MRI | - | Magnetic resonance imaging |

# CONTENTS

# *Introduction*

# INTRODUCTION

The human knee joint is a complex biomechanical system with a number of components necessary for proper functioning of the joint. The articular cartilage, menisci and ligaments are the three primary soft tissue components of the knee joint. Each of these serves a specific biomechanical function that allows for normal joint function.

**Menisci**

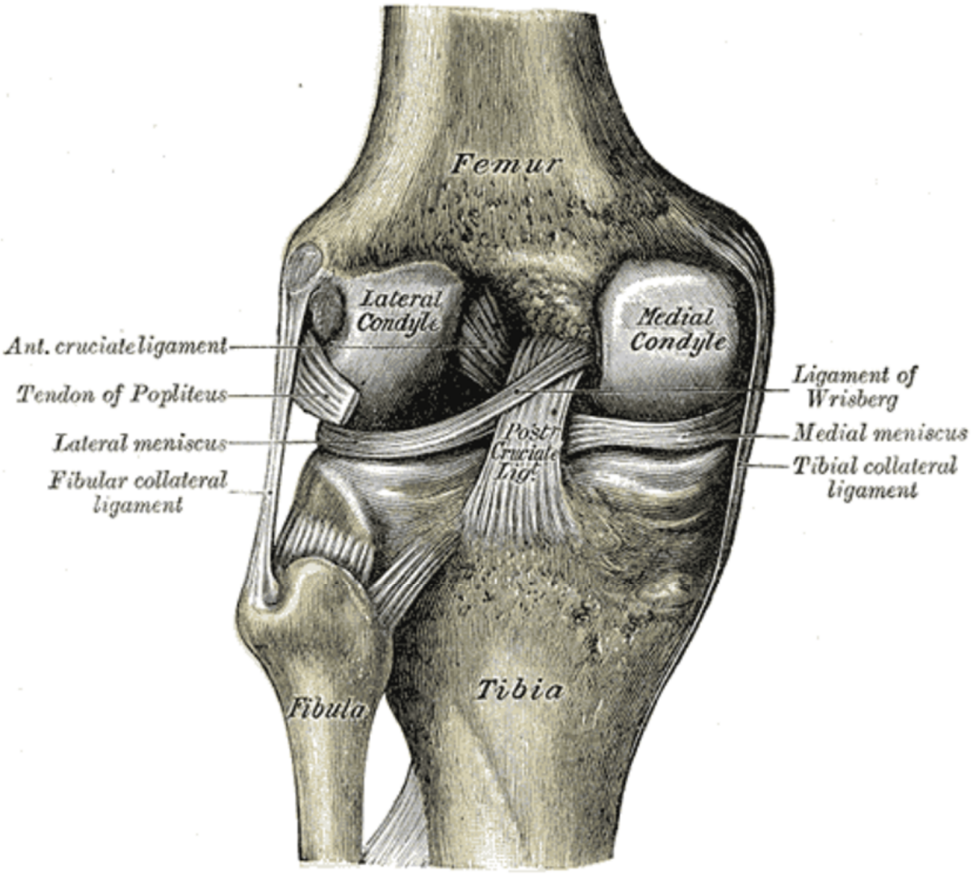
- Medial Menisci
- Lateral Menisci

**Primary ligaments**

- Anterior cruciate ligament
- Posterior cruciate ligament
- Medial collateral ligament
- Lateral collateral ligament
- Patellar ligament

The menisci (semilunar cartilages) are crescentic, intra capsular, fibro cartilaginous laminae. They serve to widen and deepen the tibial articular surfaces that receive the femoral condyles. The medial and lateral menisci cover about two-third of the surface area of the tibia plateau. Medial meniscus is semi-circular in shape and lines the medial part of the articular surface of the tibia. The lateral meniscus is circular in shape and lines the lateral part of the articular surface of

tibia. The superior surface of medial meniscus is concave and the inferior surface is flat to allow for congruity with the corresponding bony surfaces. The menisci act as shock absorbers and also function to transmit the body weight evenly across the knee joint and provide stability to the joint.




Each meniscus is divided into three zones. The anterior one-third is the anterior horn, middle one-third is the body and the posterior one-third is the posterior horn. The medial meniscus is C shaped and its posterior horn is wider than the anterior horn. The anterior horn is attached to the tibia anterior to the anterior cruciate ligament (ACL) and the posterior horn is attached to the tibia anterior to the posterior cruciate ligament (PCL). The coronary ligament attaches

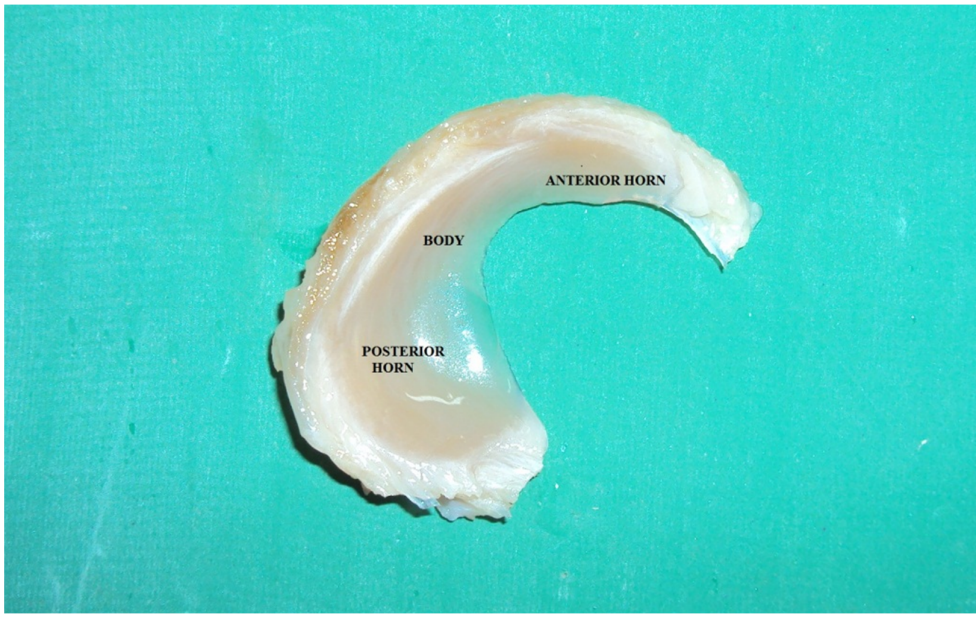


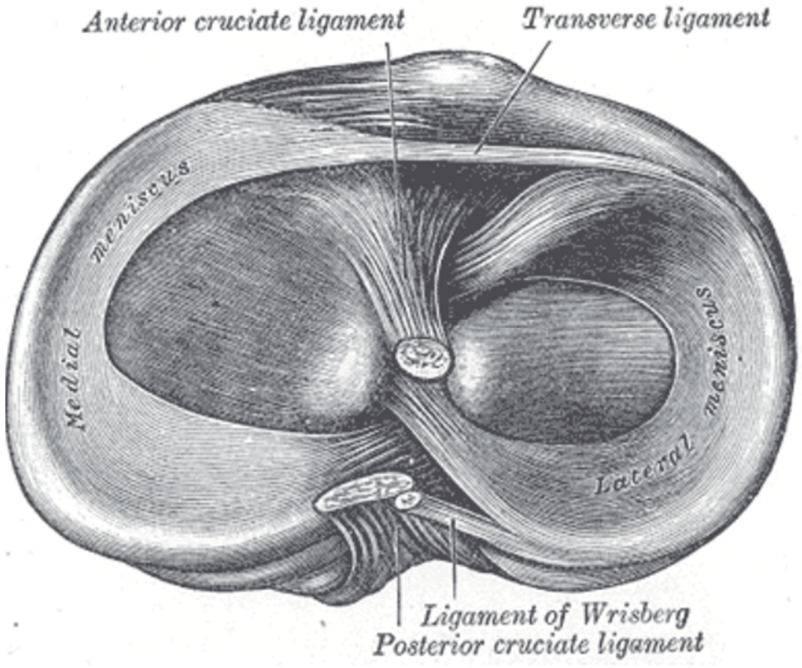

**FIG-1. MEDIAL MENISCUS**

the medial meniscus to the superior surface of tibia. The middle of the medial meniscus is attached to the medial collateral ligament. Posteriorly the meniscus is wider and the anterior crus is thinner than the posterior crus.

The meniscus has a thick outer edge and a sharp and thin non-fixed inner edge. This gives the meniscus cuneiform shape in transverse section. The outer edge of the meniscus is attached to the fibrous capsule of the knee joint. The margins of the menisci are attached to the tibial condyles by the capsular fibres of the coronary ligaments.

**Microanatomy**-

The meniscus is composed of dense fibrocartilage that in turn consists of fibroblasts and a network of collagen fibres. The fibroblasts produce Type 1 collagen.



Arterial supply to the meniscus is by the genicular arteries. The synovial lining of the attachments of the anterior and posterior horn is also supplied by the genicular arteries. The posterior part of medial and lateral menisci is supplied by the middle genicular artery. The meniscus is vascularised only up to 30% of its width in the outer rim and 35% of its width in the inner rim, thereby forming an avascular area in the middle. The surface of each meniscus has synovial fringe that extends upto 3mm. From birth, the vascularity within the meniscus continually decreases until the adult stage in which the inner two thirds of the menisci are completely avascular. It has also been shown that about 10% to 30% of the periphery of the medial meniscus obtains blood from the peri meniscal capillary plexus. Additionally, the attachments at the horn are known to have more vascularity than the rest of the meniscus with some vessels actually penetrating into its matrix. The most vascularized portion is the most peripheral part at the outer and the inner rim and is referred to as the “red zone”. The middle part of the meniscus has some vascularity in the periphery, which is called as the “red-white zone.” Finally, the central part of the meniscus, which is avascular, is known as the “white zone.” These different zones are important when considering injuries to the meniscus and these zones decide the techniques for management of the damaged menisci. Thus a “red-on-red” tear in the peripheral location has good healing potential while a “white-on-white” tear may not heal.

In the meniscus the body, anterior and posterior horns can be distinguished and these regions of the meniscus serve as the basis for the insertion of ligaments.

The firm anterior and posterior horns with bony attachments are considered important for load distribution function of the meniscus.

The shape of the meniscus bridge the gap created by the mismatch between the femoral and tibial bones and increases the contact area for weight transmission. The menisci are well adapted for their functional roles to aid in shock absorption, stability and load transfer. In the knee joint, lateral compartment transmits 70% of the load and medial compartment transmits 50% of the load through the menisci. The arrangement of collagen fibres is ideal for this type of load transmission. During compressional loading, the meniscus is compressed by axial forces and displaced radially. The root insertions act as anchors. Under compression the menisci contribute to lubrication of the joint by releasing fluid. This release of fluid helps dissipate force as well as circulate nutrients in the avascular region of the meniscus. Tissue deformation under compression improves stability and minimizes stress in the joint .

Knowledge of dimensions of the medial meniscus is of paramount importance in arthroscopic surgery and sports injury. The dimensions are not accounted in much detail in previous studies. In the present study, the dimensions of the medial meniscus are studied in detail.

Meniscal tears are one of the most common injuries to the knee. These typically occur in two ways, trauma and gradual degeneration. Degenerative tears generally occur in patients older than 40 years. They are seen in association with other degenerative changes within the joint. These degenerative tears generally

have no healing capability and are generally horizontal cleavage tears, flap tears or complex tears. Degenerative tears are very common and have often been found in asymptomatic subjects. Traumatic tears typically occur in athletically active young individuals. It usually occurs in conjunction with injuries of the anterior cruciate ligament and less frequently with injuries of the posterior cruciate ligament. Typical mechanism of injury is during internal rotation of femur, as the knee moves from flexed to extended position. This causes the menisci to split longitudinally. Traumatic injury more often occur in medial meniscus because of its larger diameter, lower mobility and thinner peripheral part.

Damage to meniscus from trauma is usually associated with knee pain and loss of function. In long term, this damage causes degenerative changes to the knee joint that includes articular cartilage degeneration, osteophyte formation and premature osteoarthritis. Due to limited vascularity, once torn the menisci has very little ability to heal and thus the majority of meniscal tears are best treated with a resection of the torn fragment, which is known as meniscectomy.

Discoid medial meniscus, a rare congenital anomaly was reported in the literature. A retrospective study of menisci assessed incidence of discoid medial meniscus at 0.12%, compared to 1.5% for discoid lateral meniscus, bilateral cases were even rarer. Discoid medial and lateral meniscus is an articular knee disorder typically presenting in the young population. While preserving meniscal tissue and function, the management of the disorder should be towards resolution of symptoms.

Osteoarthritis is the most common type of arthritis and it is a debilitating joint disease. Osteoarthritis (OA) is a multifactorial degenerative joint disease. Osteoarthritis is characterized by loss of cartilage, joint degeneration, damage to the extra-cellular matrix and alterations of subchondral bone. It is common in adults aged 25 – 74 years with the majority being older. OA is the leading cause of disability in elderly individuals. It is associated with work disability, substantial activity limitation, high health-care costs and reduced quality of life.

## CLINICAL TESTING OF MENISCAL TEAR

The meniscal injury or degeneration can be diagnosed by various clinical tests and to increase the clinician's ability various diagnostic studies have been developed to diagnose these types of disorders of the knee. The skill of the examiner, the location and severity of the injury determines the accuracy of all diagnostic tests. Since none of the tests are consistently reliable to assess the medial meniscus lesions, multitude of tests are described. So to accurately predict meniscus lesions, a composite score has been focused in recent research. This includes the combination of comprehensive history, multiple physical tests and diagnostic imaging for confirmation, while arthroscopic procedure itself remains as the gold standard test.

The various tests that are used to diagnose meniscal injury or degeneration are as follows:

1. McMurray's test
2. Thessaly test

3. Bounce Home (forced hyperextension) test

4. Axial Loaded Pivot Shift test

5. Joint Line Tenderness

6. Ego's test

7. Apley's test

All these tests have a sensitivity of about 75% and a specificity of 80%.

**IMAGING OF MENISCUS**

There are several different modalities to detect meniscal tear or degeneration of meniscus. The modalities include conventional radiograph, computed tomography, ultrasonography and magnetic resonance imaging.

**CONVENTIONAL RADIOGRAPHS**

Meniscal tear or degeneration is often missed in conventional radiograph alone, but they have an accuracy of 70% in detecting meniscal injury. Plain radiography is less used because it is mainly useful to exclude the differentials.

**CT SCAN**

The CT scan method shows the extent of involvment of meniscus but it has its own drawbacks. Computed tomography (CT) is considerably inferior when compared to MRI for meniscal imaging.

## ULTRASONOGRAPHY

Ultrasonography of knee joint meniscus is simple and useful examination method. It enables to visualize the meniscal damage and helps in the selection of graft for transplantation.

## MAGNETIC RESONANCE IMAGING

The gold standard investigation for suspected meniscal tear is magnetic resonance imaging. MRI can review intra articular and extra articular anatomical structures. It is used to confirm clinically suspected meniscal tear and thus exclude alternative diagnosis.

## ARTHROSCOPY

It is used to determine the ideal treatment. The main options include leaving the meniscus untouched, repairing the meniscus or excising a part or whole of the meniscus. Partial and full thickness tears are left alone if the injury is recent and self-healing is a possibility. Abrasion of synovium can be performed to provide tissue healing factors.

Excision was considered as the main method of managing a meniscal tear until recently. It is generally effective in reducing symptoms in open total meniscectomy.

Meniscal repair has gained importance in recent years. Meniscal repair typically has a longer rehabilitation period.

There are several methods for meniscal repair. They are arthroscopic repair and open repair. Open repair involving opening the joint cavity was the traditional method but is now becoming less desirable as arthroscopic techniques have become more advanced.

Meniscal replacement is the most recent development in this field. There are three main materials for replacement options. They are collagen scaffolds, polyurethane scaffolds and allografts. If a partial meniscectomy is performed and the peripheral meniscal rim is left intact, a scaffold can be implanted to replace the resected tissue and an attempt is made to regenerate meniscal tissue.

# *Aim of the Study*

# AIM OF STUDY

The most common injuries of the knee are the meniscal injury. Menisci play important role in knee joint biomechanics. These are semilunar discs of fibrocartilaginous tissue. In the past, menisci were considered as nearly useless and were thought to play only minor role in stabilization and joint nutrition. The movement of the menisci determines the normal function of knee joint and maintains tibio-femoral conformity, as the femoral condyles move over the tibial surface. The menisci serve as important secondary restraints to anterior, posterior and rotational motion, especially at the end points of movement. The structure of the meniscus is integral to its function as it provides protection and cushion to the knee joint. Irreparable meniscal tear and meniscal degeneration contribute to the development of osteoarthritis of the knee joint. Current medical interventions to treat meniscal injury are limited, it includes surgical repair or resection to partial or total meniscectomy. This alters the mechanics of the knee joint which contributes to the degenerative joint disease, pain and disability.

Meniscectomy is the most common procedure performed in orthopedic surgery. Current treatment of meniscal injury can be classified into three categories- meniscal repair, partial and full meniscectomy and allograft transplantation.

On the long term, it has now been recognized that removal of the meniscus causes deleterious joint consequences. Meniscus plays an important role in

maintaining knee homeostasis and joint stability. Many attempts have been made to replace the traditional meniscal repair procedures or meniscectomy with novel regenerative treatments. Since there is overturn of the therapeutic approach from meniscectomy to preservation or substitution and the open surgery is replaced by the arthroscopic surgery the basic knowledge of human meniscus requires re-appreciation.

The most common intra articular knee injury is meniscal injury. Injuries in the meniscus can cause significant pain and discomfort affecting normal daily life. Injury to the meniscus usually consists of tears in the tissue, through degenerative changes, separation from peripheral capsule and rupture of roots from the tibial plateau can occur. The tears to the meniscus can be longitudinal, bucket handle, radial and complete tear. In young and active adults they are usually traumatic and often result from twisting on a loaded flexed knee. Meniscus injury in young patients is accompanied by tear of anterior cruciate ligament. In older patients degenerative meniscal tear is more common and it occurs spontaneously.

The biomechanical and biological properties of the meniscus and their correlation with degradation such as wear and tear and tissue degeneration are important for research in the field of bio- medical engineering. Various types of meniscal disorders have been reported. While preserving meniscal tissue and function, the treatment should be directed towards the resolution of the symptoms.

Musculoskeletal pathologies affecting the knee joint are diagnosed by magnetic resonance imaging, because MRI gives a very clear picture of soft-tissue structures.

The clinical association between meniscal damage and the development of premature osteoarthritis has been well established. Knowledge of structural and biomechanical properties of the meniscus is gaining importance as this plays an important role in the development of therapeutic options for full repair of medial meniscus. It is known to be critical for the long lasting normal functioning of the knee joint.

The aim of the present study is to evaluate the morphometric data of human medial meniscus, document variation in medial meniscus dimensions between genders and to evaluate symmetry in medial meniscus measurements between the two sides and to compare it with that of the previous literature.

In the present study the following parameters are measured and analysed:

1. Width of medial meniscus
2. Thickness of medial meniscus
3. Outer circumference of medial meniscus
4. Inner circumference of medial meniscus
5. Area of medial meniscus
6. Ratio of medial meniscus area to tibial plateau area
7. Weight of medial meniscus

# *Embryology*

# EMBRYOLOGY

Foetal development of the menisci begins at approximately eight weeks as a congregation of mesenchymal stem cells. This congregation of cells further matures towards a fibroblast phenotype that lacks a defined extracellular matrix. At this stage, blood vessels are numerous and condensed in the peripheral one third of the tissue, although vessels are present throughout. As the foetus develops, these clumps of cells begin to secrete collagen that orient over time in response to physical forces of joint movement. Post natally a decrease in vascularity and cellularity with an increase in collagen content is observed. The meniscus continues to grow until early adolescence. Collagen content continues to increase from birth to 30 yrs and then it decreases with age. In addition there is thickening of collagen bundles in the ageing meniscus.

At week 14, the size of the foetal meniscus and tibia plateau areas were reported to be similar in the lateral and medial femoro-tibial compartment, whereas the increase in size of the meniscus during growth was similar medially and laterally, the area of tibialplateau is increased more rapidly in the medial side than in the lateral compartment. For this reason, the MM was found to cover a relatively smaller proportion of the medialtibial (MT) area than the lateraltibial (LT) area at later gestational stages and in adults.

The congenital abnormality of the meniscus most commonly seen in man is a discoid meniscus. The frequency of occurrence of lateral discoid meniscus is 1.5% and medial discoid meniscus is 0.3%.

In the foetus, the medial meniscus is supplied extensively by the vessels which extend upto the inner one-third. The nerve supply is also extensive.

# *Review of Literature*

# REVIEW OF LITERATURE

## WIDTH OF MEDIAL MENISCI

According to **Smillie et al (1975)**[29] ,the width is important as it determines the location and the kind of injury and also the possibility of injury. The author had said that the narrow portion of meniscus is less prone to rupture than the wider portion of the meniscus. As the anterior one-third of the medial meniscus is narrow, it is less prone to injuries than the other regions of the meniscus.

**Testut &Latarjet et al (1975)**[32] had studied about the morphometry of menisci and found that the average width of medial menisci is 10-12mm.

According to **Cailliet et al (1976)**[9] ,the average width of lateral meniscus was 12-13mm, while the average width of medial menisci was 10mm.

According to **Hayashi et al (1988)**[16] **,** width of the normal menisci was12-13mm.

**Yazaki and Cundari et al (1995)**[36] said that the lesions in the anterior horn of medial meniscus were less frequent and it usually occurs either alone.

According to **Rico and Ayala et al (1997)**[28] , the most commonly affected meniscus is the medial meniscus. The middle one-third (51%) is frequently affected followed by the posterior one- third (39%) and the anterior one- third (10%).

**Figueroa et al (1999)**[14] said that the medial meniscus showed lesser variations when compared to the lateral meniscus, and they also found that the middle one-third of the lateral meniscus is widest when compared to other regions of the meniscus.

**Didio et al (2002)**[11] had noted that in the medial meniscus, the posterior cornua was wider and the anterior extremity was sharp and thin.

**Almedia et al (2004)**[1] had measured the width of the medial meniscus at three different points (anterior one-third, middle one-third and posterior one-third). On comparing the width of the medial meniscus in these three regions, the width was widest in the posterior one-third, followed by the middle one- third, and narrowest in the anterior one-third. The authors suggest that the wider portions of the meniscus are more prone to rupture than the narrow portions of the meniscus. It is justified by the rarity of injuries of the anterior one- third of medial menisci.

**McDermott et al (2004)**[24] said that there was correlation between MM width and medial tibial plateau width. The study suggested that

MM width = 0.78 (Width of medial tibial plateau) +3.57mm.

**Murlimanju et al (2010)**[21] had studied in human foetuses and said that the posterior one-third was the widest part of the meniscus than the anterior and middle one-thirds. There was no statistically significant difference between the anterior one-third and middle one-third of the menisci.

The lateral meniscus was wider than the medial meniscus in all three regions. He compared the meniscal dimensions of the study with the adult meniscal parameters and found that the meniscal parameters of foetuses were completely different from the adult menisci. This may be due to the mesenchymal differentiation and vascularity of the menisci in the early embryonic life.

According to **Braz, PRP.1 and Silva et al(2010)[4]** , their study showed that there was no significant difference in the width of anterior one-third, middle one-third and posterior one- third of the lateral meniscus. When compared with the medial meniscus, the width was widest in the posterior one-third and narrowest in anterior one-third, due to which there is low incidence of injuries in the anterior one-third. The middle one-third, being the point of greatest tension, was most frequently injured in both menisci.

**Blocker et al (2012)[6]** studied the morphometry of medial meniscus by magnetic resonance imaging. They found that the maximal width of the medial meniscus was greater than that of the lateral meniscus.

**Mamata Panigrahi et al (2013)[20]** said that the width was assessed in three different points of MM, in anterior horn, body and posterior horn. It was found that the width of the medial menisci was less on the right side when compared to the left side. There was a significant difference in shape between the lateral meniscus and the medial meniscus.

**Amandeep Kaur et al (2013)**[2] found that there is no statistically significant difference between width of anterior and middle segment of medial meniscus. And there was no statistically significant difference in the anterior and middle segments of both right and left knee medial menisci. Further, the width of posterior segment of both sides was significantly higher than that of anterior and middle segments.

**According to Chintan et al (2014)**[8], the average width of medial meniscus was 12.44mm and that of the lateral meniscus was 11.48mm. In this study, the width of the anterior one-third of the medial and lateral meniscus was also compared and it showed significant difference.

**Narayana rao et al (2014)**[26]said that the average width of lateral meniscus and medial meniscus were 9.9 mm and 10.6 mm respectively. When the width of the three parts of the lateral meniscus was compared with the medial meniscus, there were no significant variations in width. The posterior one-third of the medial meniscus was the widest followed by the middle one-third and the anterior one-third. In the middle one-third region when the medial and lateral menisci were compared there was no significant difference. In the anterior one third, the lateral meniscus was wider than the medial meniscus.

**Nimje et al (2014)**[5] said that width of anterior horn of MM was smaller than that of the LM. Posterior horn width of both medial and lateral menisci was equal on the left side while width of posterior horn of right side meniscus is more on medial side than that of the lateral side.

**According to Sonia et al (2015)**[30], the medial meniscus width was 31.67mm and lateral meniscus width was 33.22mm. Meniscal dimensions were correlated with respective tibial plateau dimensions. There was a positive correlation with the Medial meniscus width and medial tibial plateau width which was statistically significant, linear equation for this correlation was derived.

Medial meniscal width = 0.48(medial tibial plateau width) +16.55mm

## THICKNESS

**Testut & Latarjet et al(1975)**[32] had studied the thickness of meniscus and said that the anterior one-third of the medial meniscus was the thickest part compared to posterior and middle thirds and there was no significant difference between the posterior one-third and middle one- third.

**Motta Filho et al (1999)**[23] described in their studies that the average thickness of meniscus of 4-5mm.

**Almedia et al (2004)**[1] analysed the morphometric thickness of menisci in three different points anterior one-third, middle one-third and posterior one- thirds. When the thickness of MM was related, the middle one-third of MM was found to be less followed by the posterior one-third and anterior one- thirds. The average value of thickness was found to be 5.71mm.

**Braz and Silva et al (2010)**[4] said that when the thickness of the meniscus was measured at three points, the posterior one-third of the MM was the smallest compared to the anterior one-third and middle one-third. But in the LM, the anterior one- third was the smallest compared to the posterior one-third and the middle one- third.

The author found that when both the MM and the LM compared the middle one-third is the thickest. Although the middle one- third was the thickest of both menisci, it had the highest incidence of injury. This may be due to the fixity of the anterior and posterior horns and the middle one- third is mobile which makes the

region more prone to stress. When the thickness of middle one- third of both MM and LM are compared, it was observed that the thickness of the middle one- third of the MM is smaller than that of the LM. This explains why the medial meniscus is more prone for injuries.

**Murlimanju et al(2010)**[21] studied in human foetuses and said that the thickness of the anterior one-third of the MM was the thickest part compared to posterior and middle thirds and found that there was no significant difference between the posterior one-third and middle one-third. The author also said that there was no significant difference observed among the anterior one-third, middle one-third and posterior one-third of when related to the thickness of the three parts of the medial meniscus.

**Blocker et al(2012)**[6] said that in the meniscal body, the mean lateral meniscus thickness did not differ significantly from the medial meniscus, this is opposite to the maximal thickness of the entire meniscus, which was significantly greater medially than laterally. In the anterior horn, the maximal thickness was greater laterally than medially, whereas in the posterior horn the maximal thickness was greater medially. The thickness of the posterior horn is more than the body and the anterior horn.

**Andrea Wenger et al (2012)**[3] said that the minimum thickness of the medial meniscus was 2.57mm and its maximum thickness was 6.7mm and there was a significant correlation with the thickness of the medial meniscus to the painful and painless knee OA Knee.

**Mamata Panigrahi et al (2013)**[20] said that the thickness the LM was more when compared to the thickness of MM.

**Amandeep Kaur et al(2013)**[2] said that when the outer circumference thickness of the MM is measured , the posterior one- third appeared thinner when compared to the anterior and middle thirds .There was no significant difference between these anterior and middle third.

**Chintan et al (2014)**[8] said that when the medial meniscal thickness were analysed in three different points, it was found that the middle one-third of medial meniscus was the less, followed by the anterior one-third and posterior one-thirds. The average thickness of medial meniscus was 5.77mm.When the thickness between anterior one-third, middle one-third and the posterior one third of MM were compared and it showed significant difference.

**Narayana rao et al (2014)**[26] study, the average thickness of the medial menisci was 5.47 mm and average thickness of the lateral menisci was 5.53 mm. The middle one - third of the MM was thickest followed by anterior one-third and posterior one- third. The author observed that the lateral meniscus exhibited thickest middle third and was followed by the posterior one-third and anterior one- third. It was observed that in general, the lateral meniscus was thicker than medial meniscus but the anterior one-third of the MM was significantly thicker when compared to the LM.

**Nimje et al (2014)**[5] said that the thickness of LM is more than that of MM on both right and left sides.

## OUTER CIRCUMFERENCE OF MEDIAL MENISCUS

According to **Kapandji et al (2000)**[19] , the horns of the lateral meniscus are closer together than those of the medial meniscus.

**McDermott et al (2004)**[21] had said that when the MM length and medial tibial plateau length was compared it shows positive correlation and best fit equation was MM length=0.83(medial tibial plateau length) +4.01mm.Whenthe total tibial plateau width and MM circumference were compared, it also showed positive correlation.

**Murlimanju et al (2010)**[21] studied in human foetuses and said that the outer circumference of medial meniscus is 26.6mm and the lateral meniscus was 14.72mm and the peripheral border length and inner border lengths were more in the medial meniscus than the lateral.

**Braz and Silva et al (2010)**[4] said that when the length of the outer circumference were compared, there was no significant difference between the MM and LM. The distance between the tip of anterior horn and posterior horn of the MM was found to be significantly higher when compared to the LM.

**Mamata Panigrahi et al (2013)**[20] said that the length of the MM of both right side and left side was found to be more when compared to LM of both sides.

According to **Amandeep Kaur et al (2013)**[2] , the range of outer circumference of medial menisci of knee was from 4.2-9.8 cm with mean outer circumference of 6.4 cm and found that there was no significant difference between outer

circumference of right and left side lateral menisci and the outer circumference of right and left side medial menisci.

**Chintan et al (2014)[8]** said that when the outer circumference of the MM and LM were compared there was significant difference between outer circumference of the MM and LM.

**Narayana rao et al(2014)[26]** said that the average outer circumference length of MM was 86.4 mm and the average outer circumference length of LM was 87.3 mm .When the length of the outer circumference of lateral and medial menisci were compared there was no significant difference between them . The distance from the tip of anterior horn and posterior horns of the LM is 12.6 mm and the distance from the tip of anterior horn and posterior horns of the MM was 31.8 mm.The larger interruption between the horns of MM indicates that the MM is more like a half-moon and the lateral meniscus resembles an almost complete ring thereby the difference in size of tibial plateau covered by the menisci is compensated; this can explain why the outer circumference measures of the adjacent menisci showed no significant difference. This finding is a very important clinical aspect, where the close proximity of the two horns of lateral meniscus makes lateral meniscus less prone to injury.

According to **Nimje et al (2014)[5]**, the length of medial meniscus was found to be more than that of the lateral meniscus. Dimensions on left side were larger as compared to right side which suggested that the menisci were found to be more extensive and adhered to capsule on left side when compared to right side.

**Sonia et al (2015)**[30] said that when the MM length and length of medial tibial plateau was compared it shows positive correlation with significant p value and the linear equation for correlation is MM length = 0.71(length of medial tibial plateau) + 9.01mm, and when the MM circumference and total tibial plateau width were compared it shows positive correlation with significant p value and the linear equation is MM circumference = 0.87(total plateau width) + 37.25mm,

## INNER CIRCUMFERENCE OF MEDIAL MENISCUS

**Kapandji et al (2000)**[19] had reported that distance between the horns of the LM are closer together when compared to that of the MM.

**Almedia et al (2004)**[1] said that the length between the anterior cornua and posterior cornua of MM was significantly higher when compared to the LM.

**McDermott et al (2004)**[24] said that there was poor correlation for MM length and medial tibial plateau length and also the author also observed that there was positive correlation between total tibial plateau width and MM circumference.

**Braz and Silva et al (2010)**[4] said that when the length of the inner circumference of MM and LM were compared it showed no significant difference. The distance between the anterior horn and posterior horn of the MM was higher compared to the lateral meniscus.

**Murlimanju et al(2010)**[21] studied in human foetuses and said that the inner circumference of medial meniscus is 25.14mm and the lateral meniscus is 12.59mm and the peripheral border length and inner border lengths were more in the medial meniscus than the lateral.

**Amandeep Kaur et al (2013)**[2]said that the average inner circumference of medial menisci of knee was 6.4 cm and found that there was no significant difference between inner circumference of right side and left side medial meniscus.

**Mamata Panigrahi et al (2013)**[20] said that when the length of the MM was compared to LM on both sides, the length of medial meniscus was found to be more.

**Narayana rao et al (2014)**[26] said that inner circumference of medial meniscus is 50.1mm and that of the inner circumference of lateral meniscus is 44.2mm.The study revealed that the length between the two horns of lateral meniscus is lesser than that of medial meniscus, which allowed the lateral meniscus to adjust with the moving femoral condyle more than the medial meniscus and so the injury to the lateral meniscus was less.

**Chintan Bhatt et al (2014)**[8] had observed about the inner circumference of the MM and LM that there is significant difference between inner circumference of the MM and LM.

**Sonia et al (2015)**[30] said that when the MM length and medial plateau length were compared it shows the positive correlation which was statistically significant. And there is also shows positive correlation with total tibial plateau width and MM length which was statistically significant.

**Andrea Wenger et al (2016)**[3] al said that meniscal lesion of the inner circumference were similar in both the painful and painless knees. It was also observed that the external border of the meniscus showed more extrusion in painful knees but there was no significant differences noted in the position of the internal border of meniscus.

## AREA OF MEDIAL MENISCUS

**Farias Filho et al (1985)**[13] had noted that the LM cover a higher area of the tibial plate because of its semi-circular format and the insertions of LM cornua.

**Cohen et al(1993)**[10] said that the MM and LM cover from half to two-third of articular surface of medial and lateral tibial plate and when compared that the LM cover an area higher than the MM.

**Almedia et al (2004)**[1] said that in the lateral meniscus the distance between the anterior and posterior cornua is less when compared to the MM which gives the LM the form of a ring. Because of high proximity of the insertions of lateral meniscus cornua it is less prone to lacerations. The tibial plate area on the medial side is covered by the medial meniscus significant higher than the LM in the lateral side of tibial plateau which explains the higher incidence of injuries of MM because of the higher movement of femoral condyle**.**

**Blocker et al (2012)**[6] said that the cartilage surface of the medial tibial plateau was larger than that of the lateral tibial plateauwhere 58% of the lateral tibial surface was covered with the LM and only 49% of the medial tibial surface was covered by the MM. The tibial plateau surface uncovered with meniscus was greater for the MM than for the lateral meniscus.

**Chintan et al (2014)**[8] noted that when the lateral and medial sides of the meniscal area were compared, it showed no significant difference but the tibial plate area was significantly larger in the medial side when compared to the lateral side.

**Andrea Wenger et al (2016)**[6] said that in painful osteoarthritis the medial tibial plateau covered by the medial meniscus was in smaller proportion when compared to the painless OA knees. The MM displayed more extrusion in painful knees and a greater extrusion distance, which was reflected in an uncovered surface of meniscus.

## RATIO OF AREA OF MEDIAL MENISCUS /TIBIAL PLATEAU

**Clark &Cohen et al (1993)**[10] showed that within the first 4 months of embryonic life, both the MM and LM in man already assumed their characteristic shapes. The author also said that the tibial plateau area covered by the LM is 80% and that of the MM is 60%, and the proportions remained constant throughout the growth.

**Messner and Gao et al (1998)**[22] showed that in adults, the meniscal area of the medial and lateral side showed no significant difference on comparison. But the tibial plateau area was covered in the medial side was significantly larger than in the lateral side.

**Almedia et al (2004)**[1] analysed the relation meniscus area/ tibial plate area and said that the tibial plate area covered by the MM is significant higher than the LM which explains the higher incidence of injuries in MM because of its higher action of femoral condyle.

**Blocker et al (2012)**[6] said that the cartilage surface of the medial tibial plateau was larger than that of the lateral tibial plateau. It was found that 58% of the lateral tibia was covered with the lateral meniscus and only 49% of the medial tibia was covered by the MM. The tibial plateau surface uncovered with meniscus was greater for the MM than for the LM.

**Chintan et al (2014)**[8] said that the area of medial menisci is less than the lateral menisci area whereas tibial plate area of medial side was more than that of the lateral side**.** The ratio of menisci area/ tibial plate area in the medial side is 72% and that of the lateral side was 60%. The author said that when the meniscal area

of the medial side and lateral side were compared it showed no significantly difference but the tibial plate area on the medial side was significantly larger than the lateral side. The tibial plate area covered by the MM is significant higher than the LM which explains the higher incidence of injuries in MM because of its higher action of femoral condyle.

**Nimje et al (2014)**[5] showed that ratio of antero - posterior length of medial meniscus to tibial plateau ranges from 0.88 to 0.90, while that of lateral meniscus to tibial plateau ranges from 0.80 to 0.83. Ratio of width of medial meniscus to tibial plateau ranges from 0.25 to 0.26, while that of lateral meniscus to tibial plateau ranges from 0.26 to 0.27.The MM was thinner at the periphery, much larger in diameter and usually narrower. LM is thicker at the periphery, smaller in diameter and is wider.

**David Civitarese et al (2016)**[6] said that the center of the anterior cruciate ligament and the apex of medial tibial plateau were found to be more than the center of the anterior cruciate ligament and apex of the lateral tibial. The center of the posterior cruciate Ligament and the apex of the medial tibial plateau was found to be less.

**Andrea Wenger et al (2016)**[3] said that in painful osteoarthritis the medial tibial plateau covered by the medial meniscus was in smaller proportion when compared to the painless OA knees. The MM displayed more extrusion in painful knees and a greater extrusion distance, which is reflected in an uncovered surface of meniscus

**WEIGHT**

According to **Blocker et al (2012)**[6] , the volume of the lateral meniscus was very similar to that of the medial meniscus. The lateral meniscus displayed significantly greater tibial area and fibular area than the medial meniscus

**Amandeep Kaur et al (2013)**[2] said that there was no statistically significant difference was found between weight of right and left knee medial meniscus.

**Andrea Wenger et al (2016)**[3] said that the volume of medial meniscus in osteoarthritis knee with painful knee and painless knee were observed and said that there is no significant difference in volume of medial meniscus.

# *Materials & Methods*

# MATERIALS AND METHOD

## STUDY MATERIALS

1. 25 embalmed cadavers (twelve male and thirteen female)
2. Measuring tape
3. Threads
4. Graph paper
5. Digital vernier callipers
6. Linear scale
7. Pin
8. Electronic weight scale

## STUDY METHOD

Dissection method

## SPECIMEN SELECTION

25 embalmed cadavers were selected from the cadavers allotted to I MBBS students in the Institute of Anatomy, Madras Medical College, and Chennai from which 50 specimens of medial meniscus were taken for the study.

## DISSECTION METHOD

The medial menisci from 50 knee joints of 25 adult cadavers were properly dissected and dried. There were 12 male and 13 female cadavers. The cadavers were preserved in 10% formaldehyde solution. The cadavers which had

## MEASUREMENT OF WIDTH OF MEDIAL MENISCUS


**FIG-2 : ANTERIOR ONE - THIRD**


**FIG-3 : MIDDLE ONE - THIRD**


**FIG-4 : POSTERIOR ONE - THIRD**

musculoskeletal anomalies were excluded from the study. The exclusion criteria used were:

a) Knee joint with meniscal tear

b) Tibia plateau with fracture

c) Knee joint with previous surgery

After skin and muscles are dissected, the menisci were approached by the longitudinal incision made anteriorly on each side of the joint capsule, Muscular and ligamentous attachments around the knee joint were separated. Neurovascular structures around the knee joint were cut and reflected. Patella was reflected inferiorly by reflecting ligamentum patellae. The patellar ligament is cut transversely and the collateral ligaments are also cut transversely. The condyles were detached circumferentially from their soft tissue attachments and the intra articular ligaments and joint capsule were cut so that the meniscus and the tibial plateau are expose clearly. The morphological parameters of the medial meniscus were examined.

The following parameters were included in the study

**1. WIDTH OF MEDIAL MENISCUS**

To measure the width of medial menisci, first a thread is positioned in the outer circumference from the apex of the anterior cornu to the apex of the posterior cornu of meniscus. With a linear scale the length of the thread was measured. The values were registered and divided by four (25%), establishing three points on the line: one anterior, one medium and one posterior., the thread is

## MEASUREMENT OF THICKNESS OF THICKNESS OF MEDIAL MENISCUS

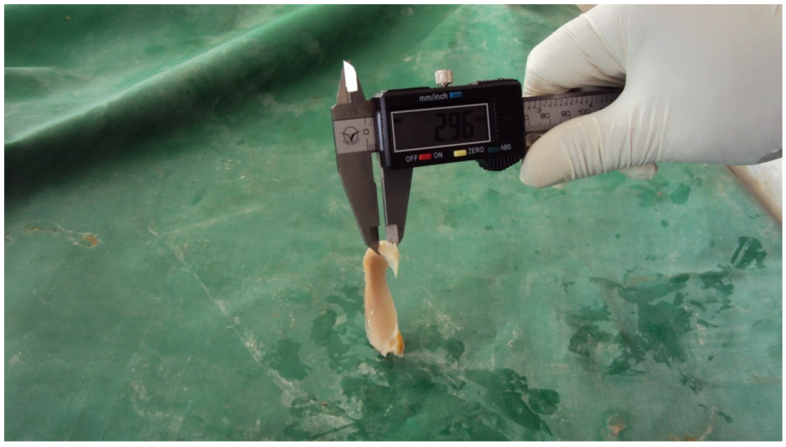


**FIG-5,ANTERIOR ONE-THIRD**

**FIG-6, IN MIDDLE ONE-THIRD**

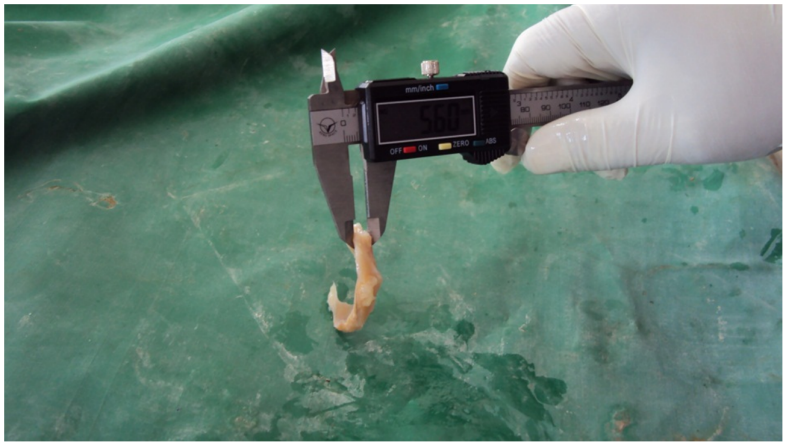
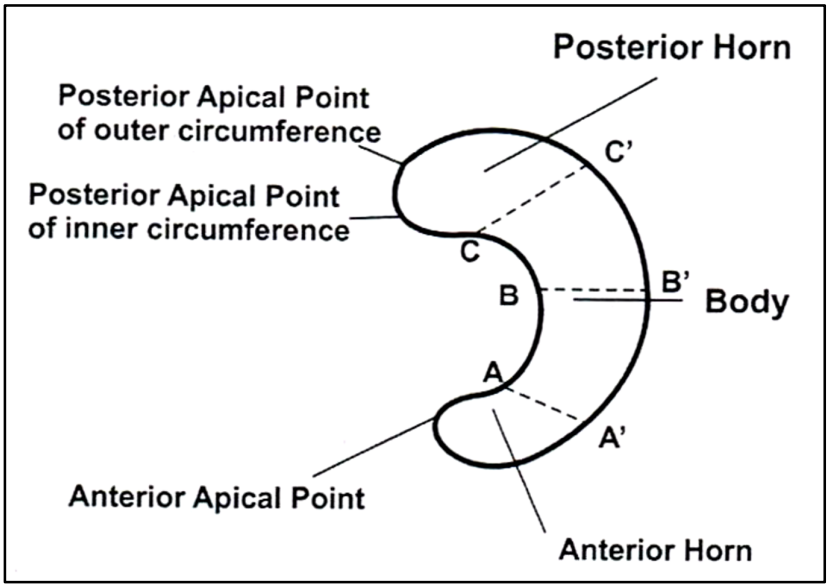


**FIG-7,IN POSTERIOR ONE-THIRD**

again positioned on the outer circumference of meniscus, enabling that the three points were transferred to it similarly a thread is positioned in the inner circumference from the apex of anterior cornu to the apex of posterior cornu of meniscus. With a linear scale the length of the line was measured. The values were registered and divided by four (25%), establishing three points on the line: one anterior, one medium and one posterior. The three points is transferred to the inner circumference. Draw the line connecting the points. Measure the width of the MM at the three corresponding points of anterior, middle and posterior




**2. THICKNESS OF MEDIAL MENISCUS**

To measure the thickness of outer circumference of menisci, first a thread is positioned from the apex of anterior cornu to the apex of posterior cornu of meniscus. With a linear scale the length of the line was measured. The values were registered and divided by four (25%), establishing three points on the line: one anterior, one medium and one posterior, the thread is again positioned on the

**MEASUREMENT OF OUTER CIRCUMFERENCE OF MEDIAL MENISCUS**

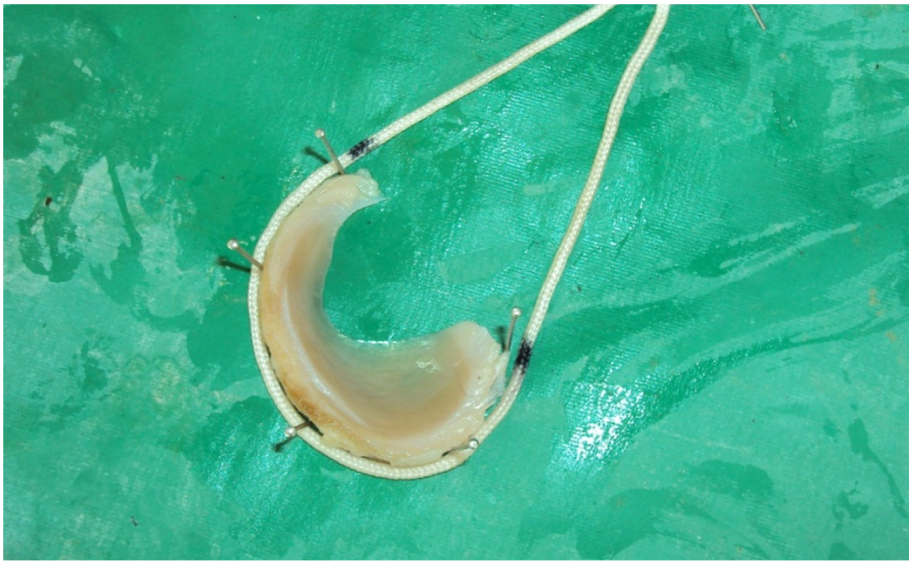


**FIG-8**

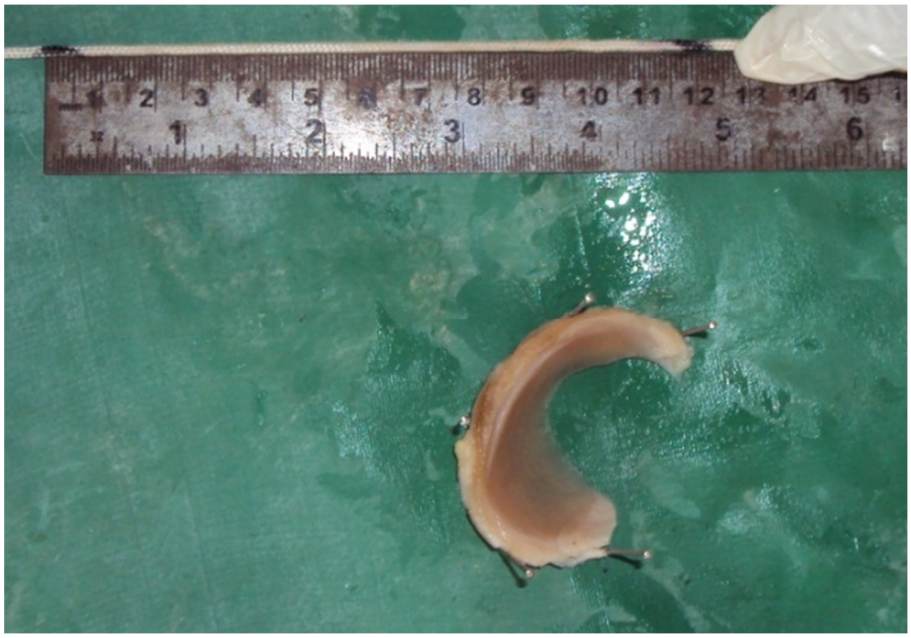


**FIG-9**

**MEASUREMENT OF INNER CIRCUMFERENCE**

**OF MEDIAL MENISCUS**

**FIG-10**

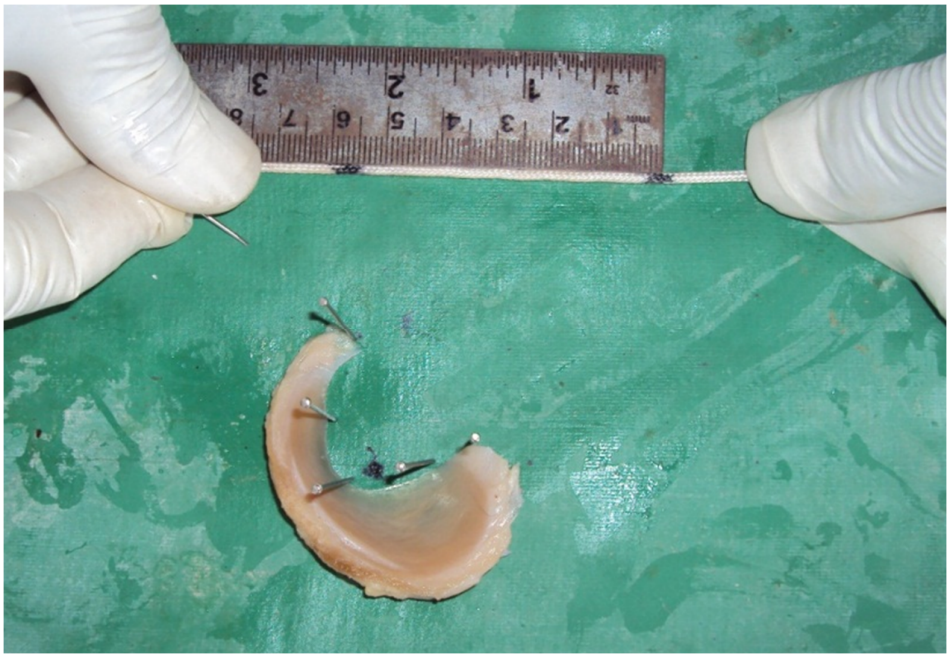


**FIG-11**

## MEASUREMENT OF AREA OF MEDIAL MENISCUS

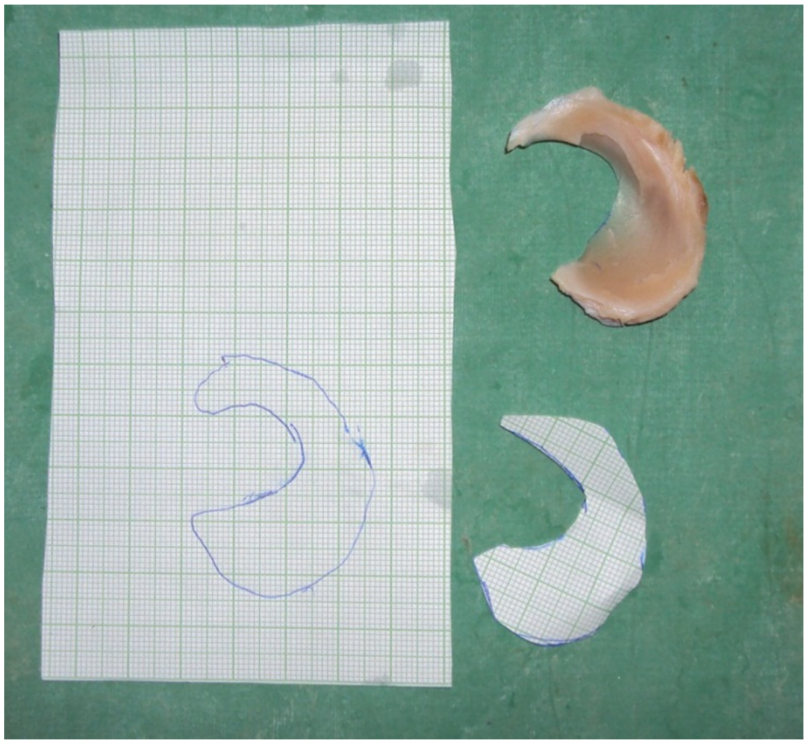


**FIG-12**

outer circumference of meniscus, enabling that the three points were transferred to it. From each point in the outer circumference the thickness of medial meniscus is measured by vernier calliper

**3. OUTER CIRCUMFERENCE OF MEDIAL MENISCUS**

The length of medial meniscus is measured as outer circumference and inner circumference. The outer circumference length of each meniscus was measured, for this; a piece of thread was placed across the outer edge of the meniscus from the apex of the anterior horn to the apex of posterior horn. Using a linear scale the thread length was measured.

**4. INNER CIRCUMFERENCE OF MEDIAL MENISCUS**

The length of medial meniscus is measured as outer circumference and inner circumference. The inner circumference of each meniscus was measured, by a piece of thread was placed across the inner edge of the meniscus from the apex of the anterior horn to the apex of the posterior horn. Using a linear scale the thread length was measured.

**5. AREA OF MEDIAL MENISCUS**

Menisci area was calculated by the measurement of the contour of menisci using a litmus paper. The litmus paper is then drawn over the graph paper; its area was calculated by the graph paper. We took circumference of the menisci by the litmus paper and posted it on the graph paper. Number of the small square in the circumference gives the area in mm2.

## 6. RATIO OF AREA OF MEDIAL MENISCUS/AREA OF TIBIAL PLATEAU

To calculate the area of menisci and the area of tibial plateau the adopted procedure for the measurement of the contour of menisci and tibial plateau were obtained using a litmus paper. Then, its area was calculated by the graph paper. We took circumference of the menisci and tibial plateau by the litmus paper and posted it on the graph paper. Number of the small square in the circumference gives the area in mm2.

## 7. WEIGHT OF MEDIAL MENISCUS

Weight of the medial meniscus was taken using electronic weighing machine with the accuracy of milligrams.

The morphometric parameters were measured using digital vernier caliper, linear scale, graph paper. All the parameters except the weight were measured in the unit of millimeter with an accuracy of 0.01mm, the weight was measured in milligrams using digital physical balance with an accuracy of 0.01mg.the data obtained were analyzed using SPSS software.

# *Observation*

# OBSERVATION

The dissection was carried out in 25adult cadavers, 50 medial meniscus were properly dissected and dried .the various parameters were analysed, tabulated and comparison were made

**MORPHOMETRIC PARAMETERS**

**1. WIDTH OF MEDIAL MENISCUS**

The width was measured at three points - the anterior one-third, middle one- third, and posterior one-third. The digital vernier calliper was positioned from the outer edge to the inner edge of each meniscus from each point.

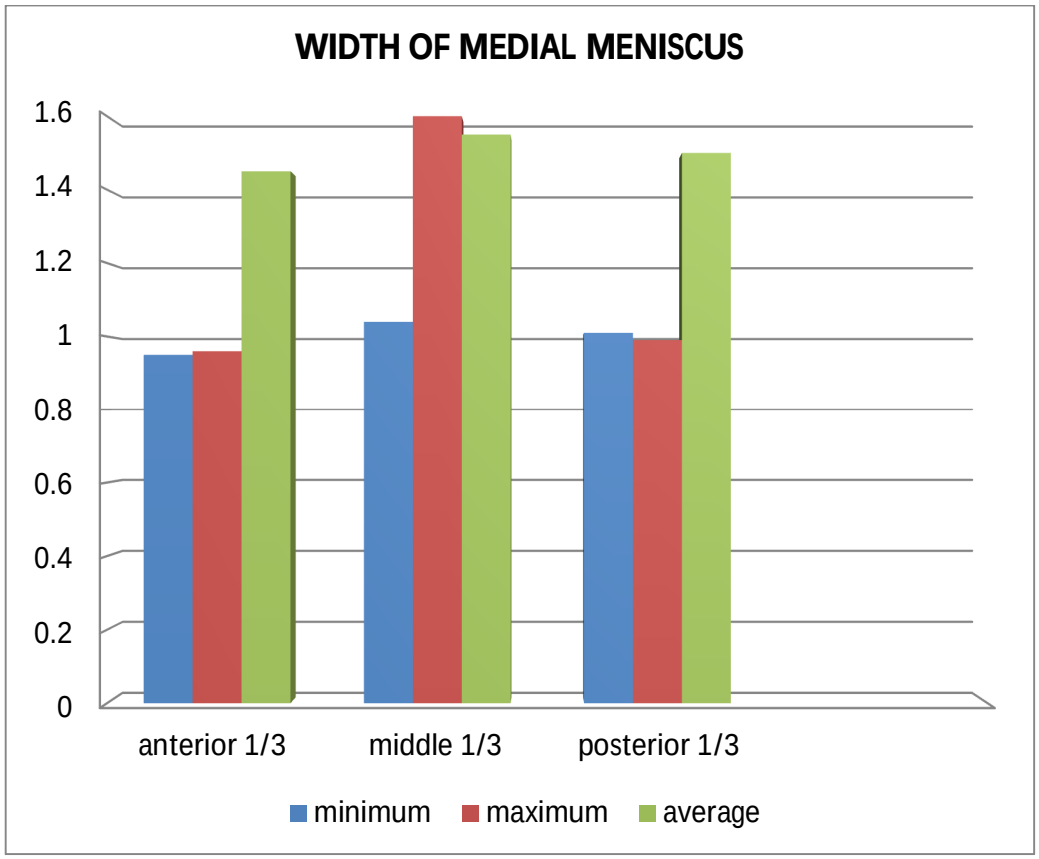
The mean value, standard deviation and range of the width of 50 medial meniscus are tabulated below

**TABLE NO 1**

| STATISTICAL DATA | ANTERIOR 1/3 | MIDDLE 1/3 | POSTERIOR 1/3 |
|---|---|---|---|
| Minimum | 0.95cm | 0.96cm | 1.45cm |
| Maximum | 1.04cm | 1.6cm | 1.55cm |
| Average | 1.01cm | 0.99cm | 1.50cm |
| S.D | 0.21 | 0.22 | 0.27 |

The average medial meniscus width in the anterior 1/3 is 1.01cm with the standard deviation of 0.21, the average medial meniscus width in the middle 1/3 is 0.99cm with the standard deviation of 0.22, the average width of the medial meniscus in the posterior 1/3 is 1.5cm with the standard deviation of 0.27.

**CHART NO. 1**



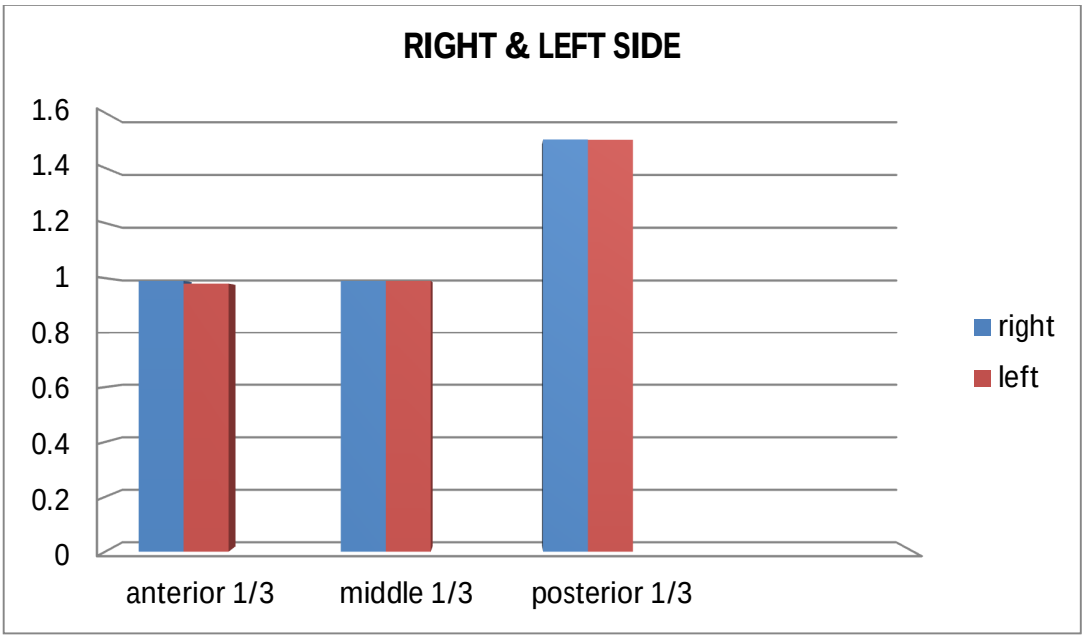

The medial meniscus width seen in left and right sided specimens was assessed, tabulated and comparison was made.

**TABLE NO. 2**

| **Width of the medial meniscus Mean(cm)** | | **Anterior 1/3** | **Middle 1/3** | **Posterior1/3** |
|---|---|---|---|---|
| | Right | 0.99cm | 0.99cm | 1.50cm |
| | Left | 0.98cm | 0.99cm | 1.50cm |
| | p-value | ≥0.05 | ≥0.05 | ≥0.05 |

The mean width of anterior 1/3 of the medial meniscus on the right side was found to be 0.99cm and the mean width of anterior 1/3 of the medial meniscus on the left side was found to be 0.98cm and the p-value derived using t-test did not show any significance. The mean width of the middle 1/3 of the right sided medial meniscus was found to be 0.99cm and the mean width of the middle 1/3 of left sided medial meniscus was found to be 0.99cm and the p-value derived using t-test did not show any significance. The mean width of the right sided specimen of medial meniscus in its posterior 1/3 was found to be 1.50cm and the mean width of the left sided medial meniscus in the posterior 1/3 was found to be 1.50cm and the p-value derived using t-test did not show any significance.

**CHART NO. 2**




The width of the medial meniscus seen in males and females was assessed and tabulated and compared.

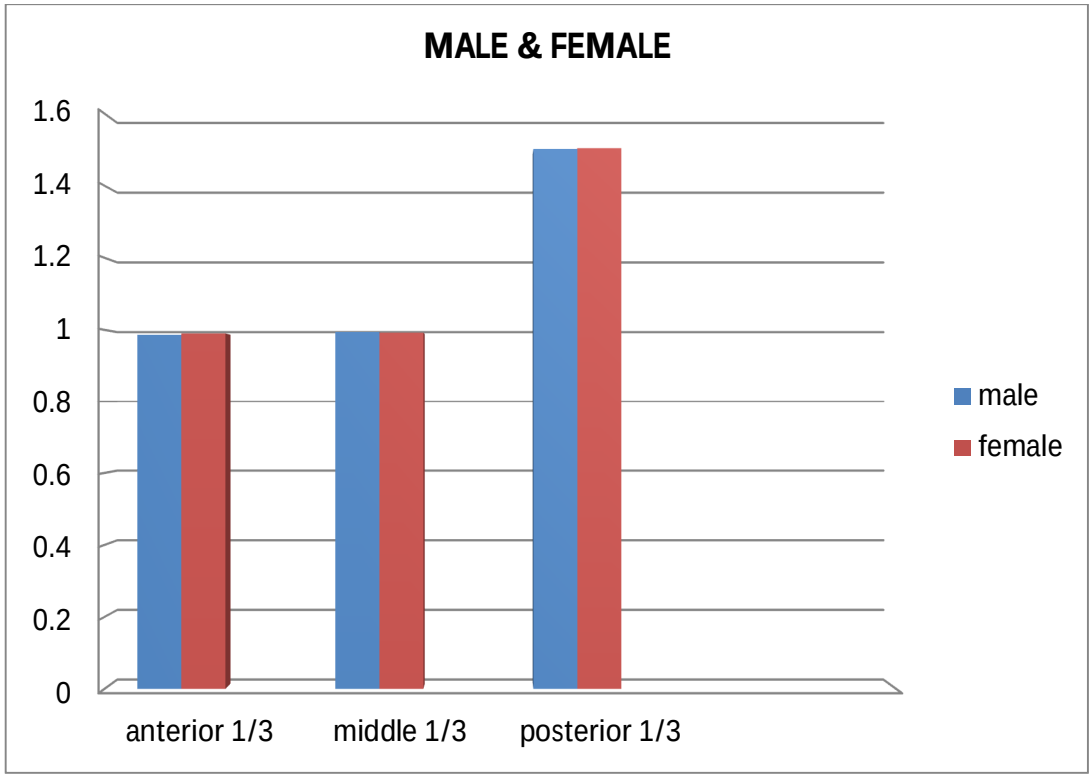
**TABLE NO 3**

| | | Anterior 1/3 | Middle 1/3 | Posterior1/3 |
|---|---|---|---|---|
| **Width of the medial meniscus Mean(cm)** | Male | 0.99cm | 0.99cm | 1.50cm |
| | Female | 0.99cm | 0.99cm | 1.50cm |
| | p-value | ≥0.05 | ≥0.05 | ≥0.05 |

The mean width of anterior 1/3 of medial meniscus in males was found to be 0.99cm and the mean width of anterior 1/3 of medial meniscus in females was found to be 0.99cm and the p-value derived using t-test did not show any significance. The mean width of middle 1/3 of medial meniscus in males was found to be 0.99cm and that in females was found to be 0.99cm and the p-value

derived using t-test did not show any significance. The mean width of posterior 1/3 of medial meniscus in males was found to be 1.50cm and the same in females was 1.50cm and the p-value derived using t-test did not show any significance.

**CHART NO. 3**



## 2. THICKNESS OF MEDIAL MENISCUS

The thickness was measured at three points - the anterior one- third, middle one- third and posterior one- third. The digital vernier calliper was positioned from the outer edge to the inner edge of each meniscus at each point.

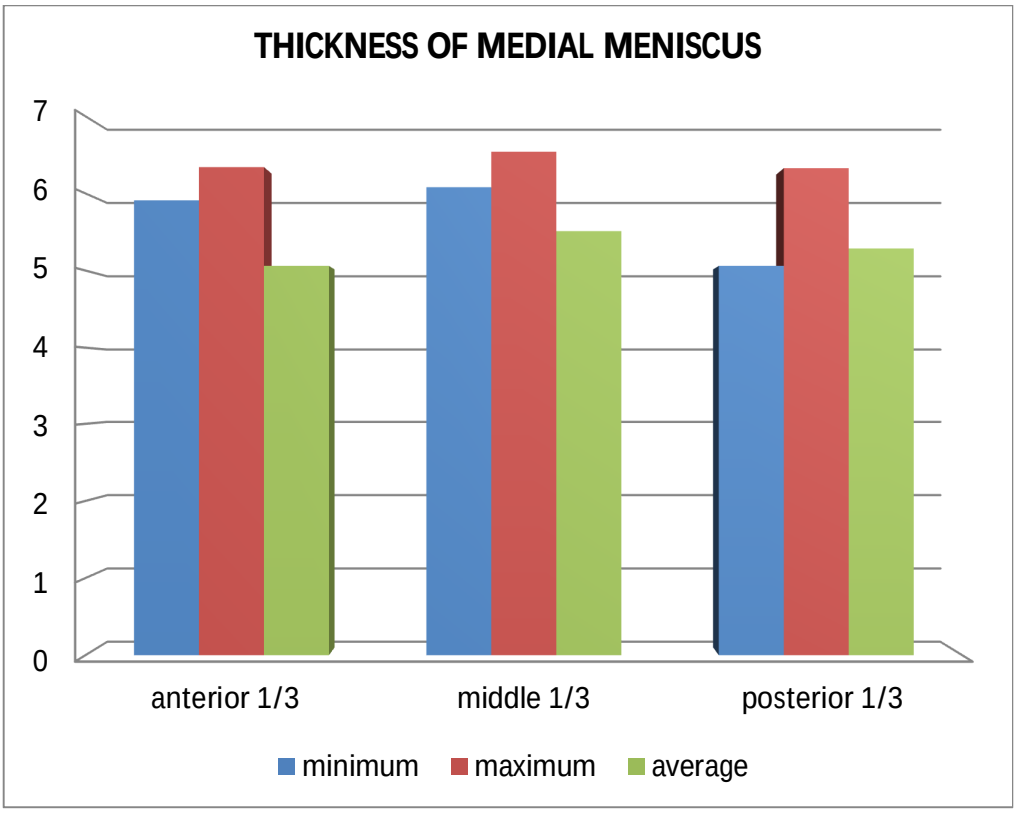
The mean value, standard deviation and range of the thickness of 50 medial meniscus were tabulated.

**TABLE NO. 4**

| STATISTICAL DATA | ANTERIOR 1/3 | MIDDLE 1/3 | POSTERIOR 1/3 |
|---|---|---|---|
| Minimum | 5.91mm | 6.08mm | 5.06mm |
| Maximum | 6.34mm | 6.54mm | 5.51mm |
| Average | 6.14mm | 6.33mm | 5.29mm |
| S D | 0.109 | 0.124 | 0.107 |

The average medial meniscus thickness in the anterior 1/3 is 6.14cm with the standard deviation of 0.109, the average medial meniscus thickness in the middle 1/3 is 6.33cm with the standard deviation of 0.124, the average width of the medial meniscus in the posterior 1/3 is 5.29cm with the standard deviation of 0.107.

**CHART NO. 4**



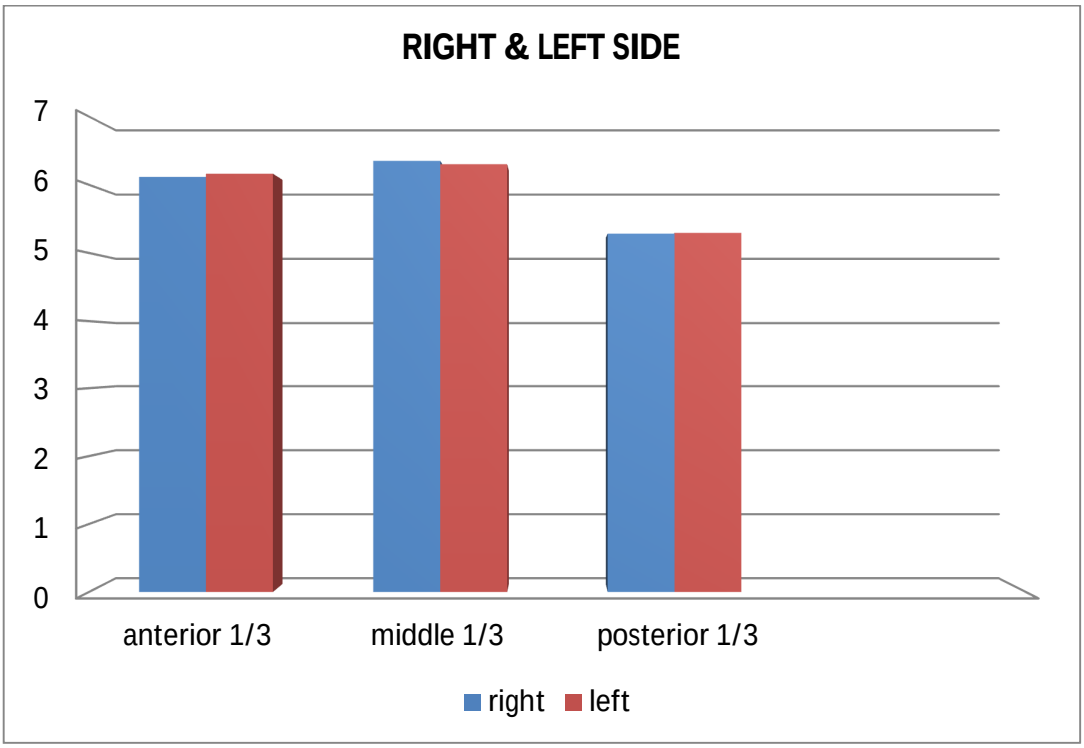

The thickness of the medial meniscus seen in left and right sided specimens was assessed and tabulated and comparison made.

**TABLE NO. 5**

| | | **Anterior 1/3** | **Middle 1/3** | **Posterior1/3** |
|---|---|---|---|---|
| **Thickness of the medial meniscus (cm)** | Right | 6.11mm | 6.35mm | 5.28mm |
| | Left | 6.16mm | 6.30mm | 5.29mm |
| | p-value | ≥0.05 | ≥0.05 | ≥0.05 |

The mean thickness of the right sided specimen of medial meniscus in its anterior 1/3 was found to be 6.11mm and the mean thickness of the left sided specimen of medial meniscus in its anterior 1/3 was found to be 6.16mm and the p-value derived using t-test did not show any significance. The mean thickness of the right sided specimen of medial meniscus in the middle 1/3 was found to be 6.35mm and the mean thickness of the left sided specimen of medial meniscus in the middle 1/3 was found to be 6.30mm and the p-value derived using t-test did not show any significance. The mean thickness of the right sided specimen of medial meniscus in the posterior 1/3 was found to be 5.28mm and the mean thickness of the left sided specimen of medial meniscus in its posterior 1/3 was found to be 5.29mm and the p-value derived using t-test did not show any significance.

**CHART NO. 5**




The thickness of the medial meniscus seen in male and females was assessed, tabulated and comparison was made.

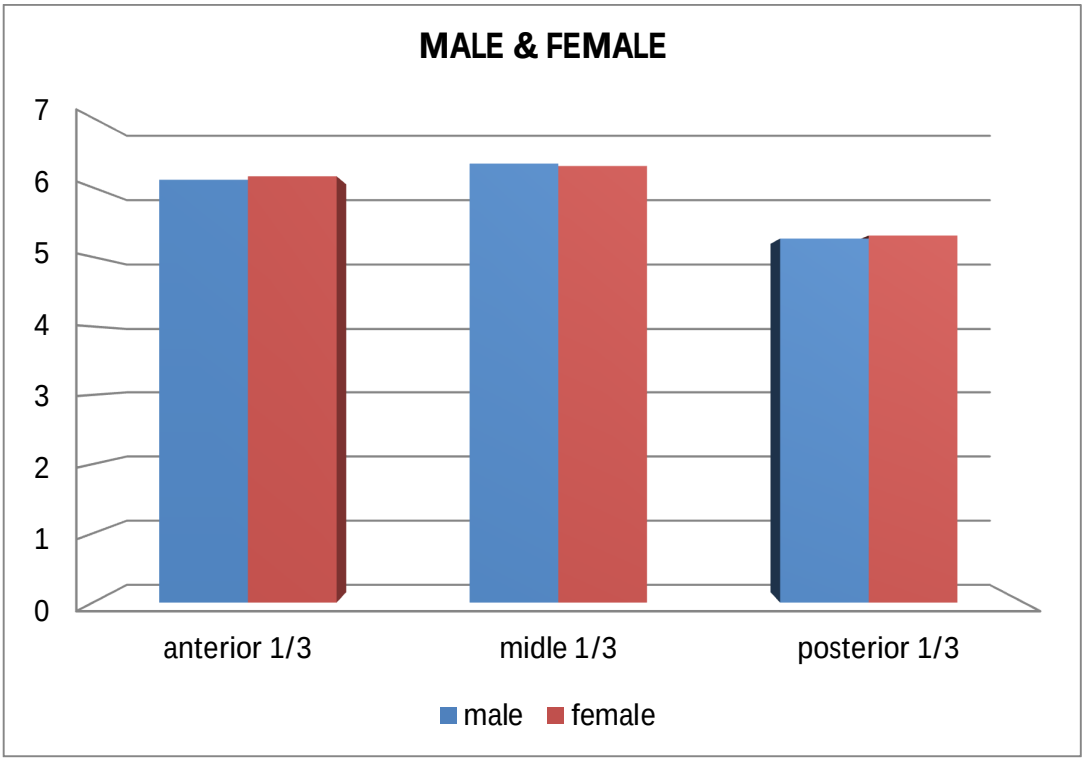
**TABLE NO 6**

| | | **Anterior 1/3** | **Middle 1/3** | **Posterior 1/3** |
|---|---|---|---|---|
| **Thickness of the medial meniscus Mean(mm)** | male | 6.11mm | 6.34mm | 5.26mm |
| | Female | 6.16mm | 6.30mm | 5.31mm |
| | p-value | ≥0.05 | ≥0.05 | ≥0.05 |

The mean thickness of the medial meniscus in males in anterior 1/3 was found to be 6.11mm and the mean thickness of the medial meniscus in females in the anterior 1/3 was 6.16mm and the p-value derived using t-test did not show any significance. The mean thickness of medial meniscus in males in the middle 1/3 was found to be 6.34mm and the mean thickness of the medial meniscus in females in the middle 1/3 was found to be 6.31mm and the p-value derived using t-test did not show any significance. The mean thickness of the medial meniscus in males in the posterior 1/3 was found to be 5.26mm and the mean thickness of the medial meniscus in females in the posterior 1/3 was found to be 5.31mm and the p-value derived using t-test did not show any significance.

The whole range of values is shown in the histogram.

**CHART NO. 6**



### 3. OUTER CIRCUMFERENCE OF MEDIAL MENISCUS

The length of the outer circumference was measured from anterior horn to the posterior horn of the medial meniscus.

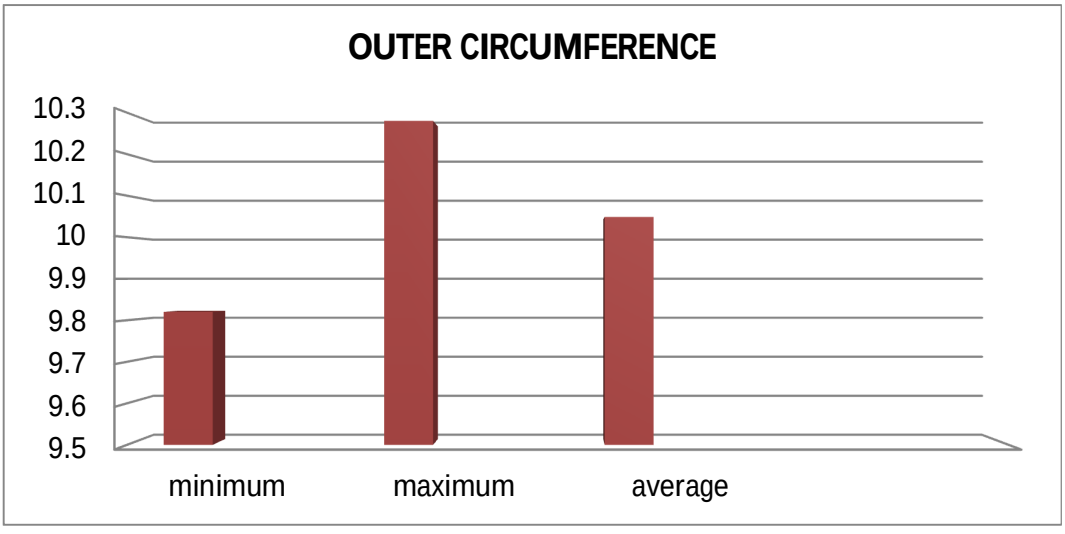
The mean value, standard deviation and range of the outer circumference of 50 medial menisci are tabulated below.

**TABLE NO. 7**

| STATISTICAL DATA | OUTER CIRCUMFERENCE |
|---|---|
| Minimum | 9.82cm |
| Maximum | 10.28cm |
| Average | 10.05cm |
| S.D | 0.12 |

The average outer circumference of the medial meniscus was 10.05cm with the standard deviation of 0.12.

**CHART NO. 7**



The outer circumference of the medial meniscus seen in left and right side were assessed, tabulated and comparison was made.

**TABLE NO 8**

| **Outer circumference of the medial meniscus Mean(cm)** | **Right side** | **Left side** | **p-value** |
|---|---|---|---|
| | 10.05cm | 10.05cm | ≥0.05 |

The mean on the right side was found to be 10.05cm and the mean on the left side was found to be10.05cm. The p-value derived using t-test did not show any significance.

The outer circumference of the medial meniscus seen in male and female was assessed, tabulated and comparison made.

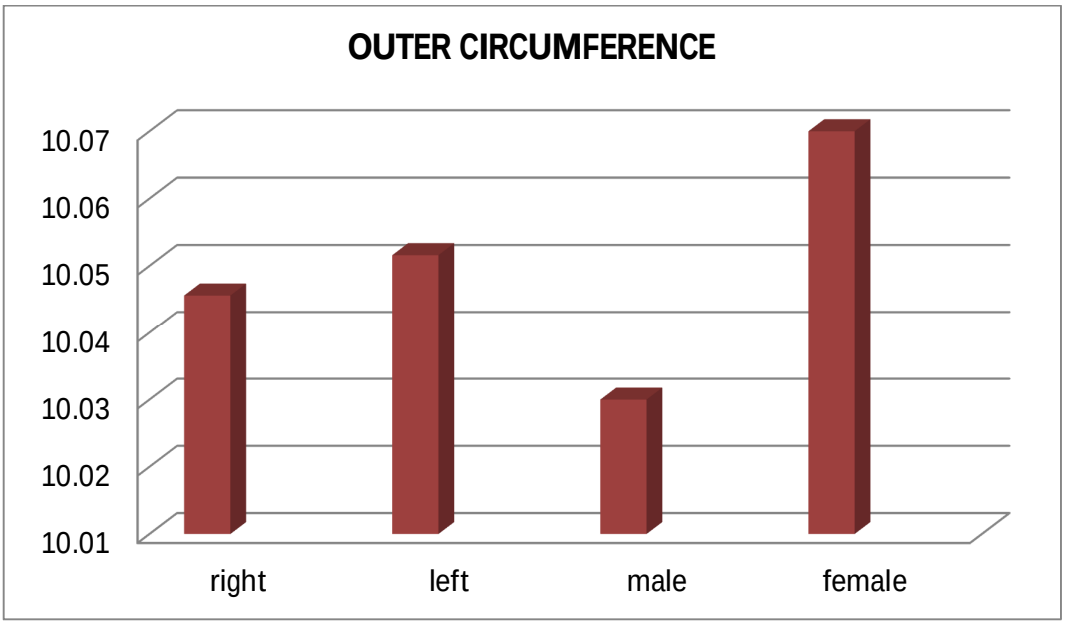
**TABLE NO 9**

| **Outer circumference of the medial meniscus Mean(cm)** | **Male** | **female** | **p-value** |
|---|---|---|---|
| | 10.03cm | 10.07cm | ≥0.05 |

The mean of the outer circumference of male was found to be 10.03cm and the mean of the outer circumference of female was 10.07cm. The p-value derived using t test did not show any significance.

The whole range of values is shown in the histogram

**CHART NO. 8**




**4. INNER CIRCUMFERENCE OF MEDIAL MENISCUS**

The length of the inner circumference is measured from the anterior horn to the posterior horn of medial meniscus.

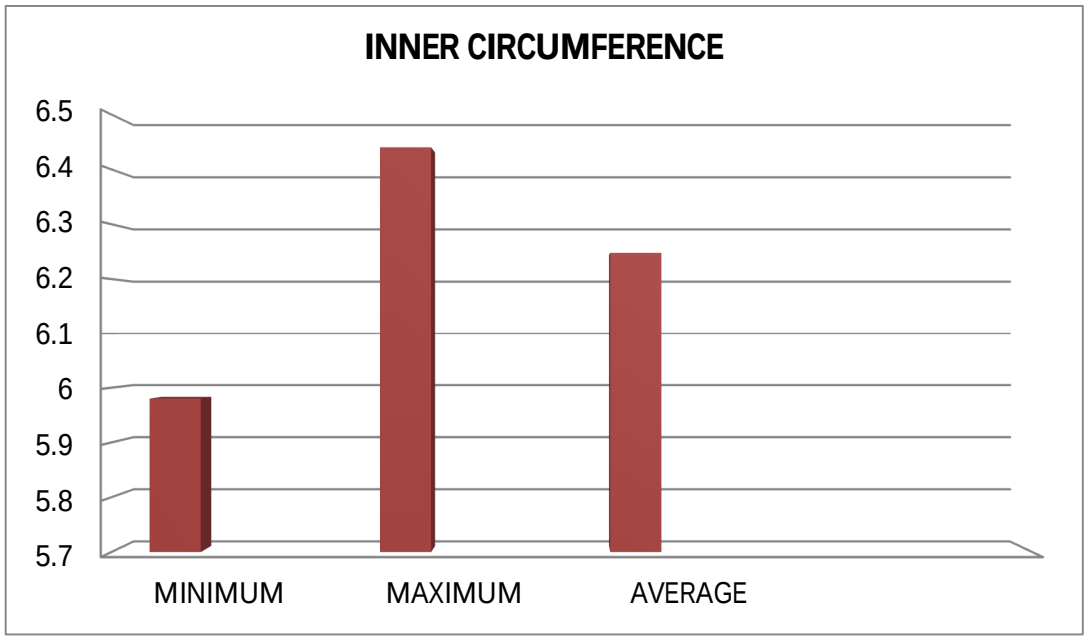
The mean value, standard deviation and range of the inner circumference of 50 medial menisci were tabulated.

**TABLE NO 10**

| STATISTICAL DATA | INNER CIRCUMFERENCE |
|---|---|
| Minimum | 5.98cm |
| Maximum | 6.44cm |
| Average | 6.25cm |
| S.D | 0.12 |

The average inner circumference of medial meniscus was 6.25cm with standard deviation of 0.12. Maximum inner circumference of medial meniscus was 6.44cm and the minimum inner circumference of medial meniscus was 5.98cm.

**CHART NO. 9**




The inner circumference of the medial meniscus seen on left side and right side were assessed, tabulated and comparison made.

**TABLE NO 11**

| Inner circumference of the medial meniscus mean(cm) | Right | Left | p-value |
|---|---|---|---|
| | 6.26cm | 6.24cm | ≥0.05 |

The mean of the right side was found to be 6.26cm and the mean of the left side was found to be 6.24cm and the p-value derived using t-test did not show any significance.

The inner circumference of the medial meniscus seen in male and female specimen was assessed, tabulated and comparison made.

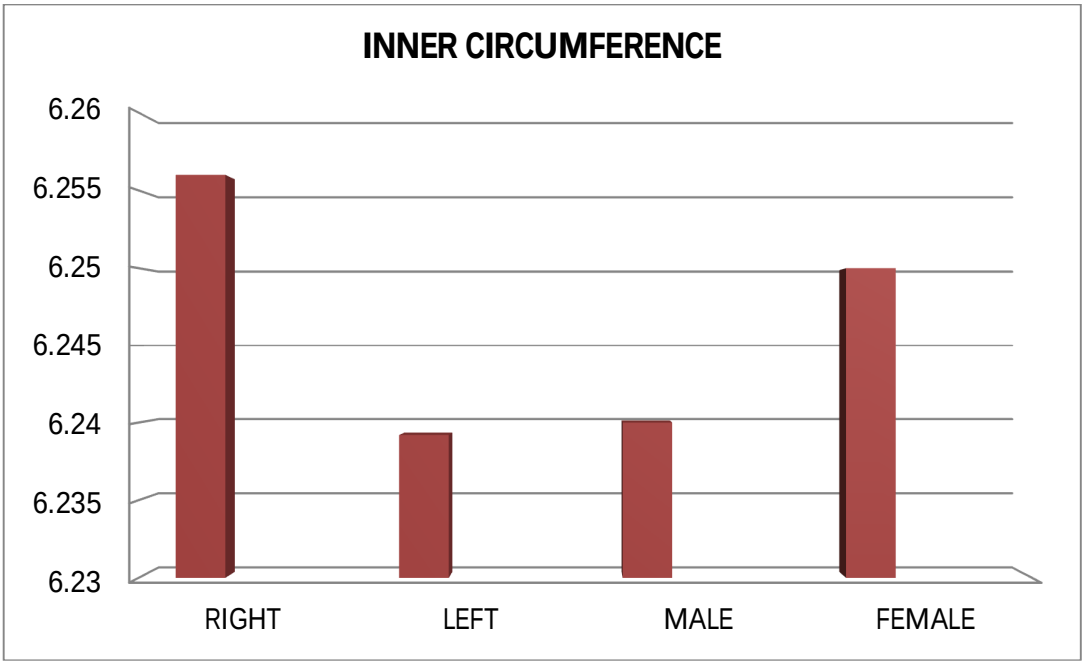
**TABLE NO. 12**

| Inner circumference of the medial meniscus (cm) | Male | Female | p-value |
|---|---|---|---|
| | 6.24cm | 6.25cm | ≥0.05 |

The mean of the male was found to be 6.24cm and the mean of the female specimen was 6.25cm and the p-value derived using t test did not shows any significance.

The whole range of values was shown in the histogram

**CHART NO. 10**




## 5. AREA OF MEDIAL MENISCUS

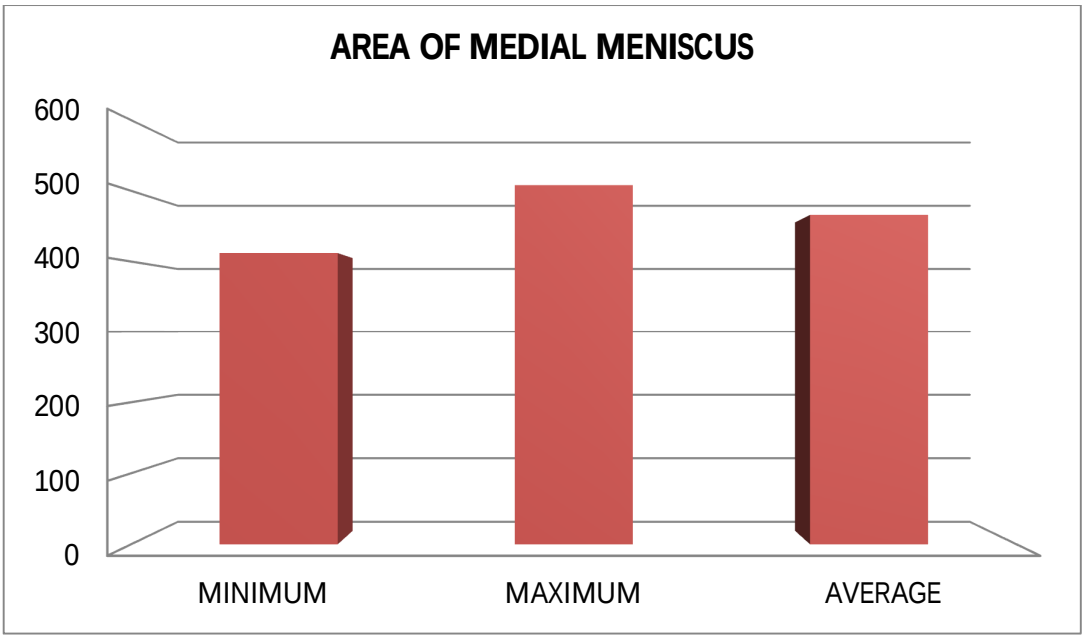
The mean value, standard deviation and range of the area of 50 medial menisci were tabulated below.

**TABLE NO. 13**

| STATISTICAL DATA | Surface area of medial meniscus |
|---|---|
| Minimum | 412mm$^2$ |
| Maximum | 508mm$^2$ |
| Average | 466mm$^2$ |
| S.D | 24.06 |

The average area of medial meniscus was 466mm$^2$ with standard deviation of 24.06. The maximum area of medial meniscus was 508mm$^2$ and the minimum area of medial meniscus was 412mm$^2$.

**CHART NO. 11**




Area of the medial meniscus on the right and left sides was assessed, tabulated and comparison made.

**TABLE NO 14**

| **Area of the medial meniscus Mean(mm$^2$)** | **Right** | **Left** | **p-value** |
|---|---|---|---|
| | 465.76mm$^2$ | 466.24mm$^2$ | ≥0.05 |

The mean on the right side was found to be 465.76mm$^2$ and the mean on the left side was found to be 466.24mm$^2$. The p-value derived using t-test did not show any significance.

The area of the medial meniscus seen in males and females was assessed, tabulated and comparison made.

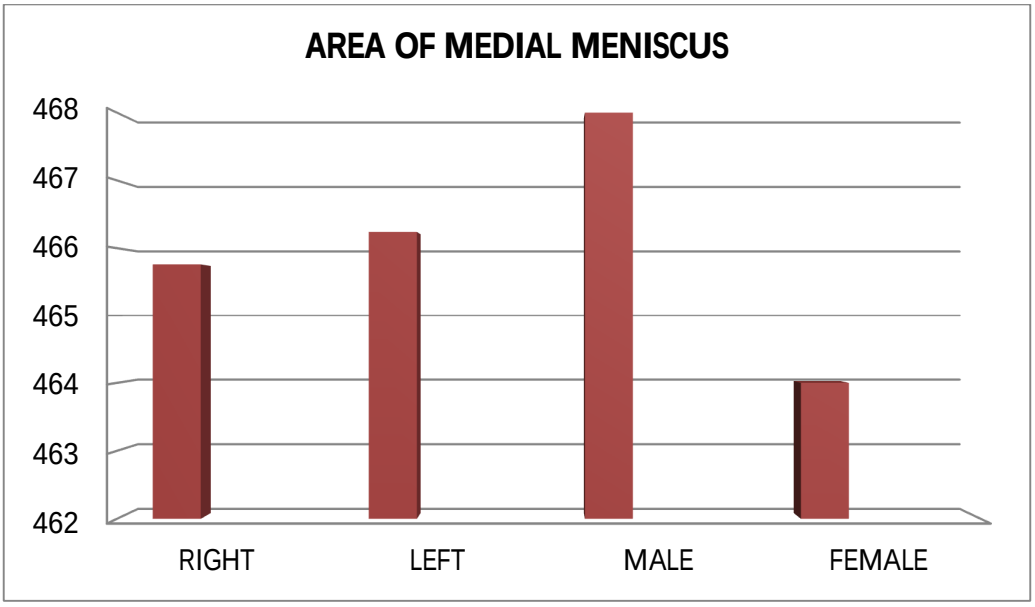
**TABLE NO 15**

| Area of the medial meniscus Mean(mm) | Male | Female | p-value |
|---|---|---|---|
| | 468mm$^2$ | 464mm$^2$ | ≥0.05 |

The mean was found to be 468mm$^2$ in males and the mean was 464mm$^2$ in females. The p-value derived using t test did not show any significance.

The whole range of values is shown in the histogram.

**CHART NO. 12**



## 6. RATIO OF AREA OF MEDIAL MENISCUS/AREA OF TIBIAL PLATEAU

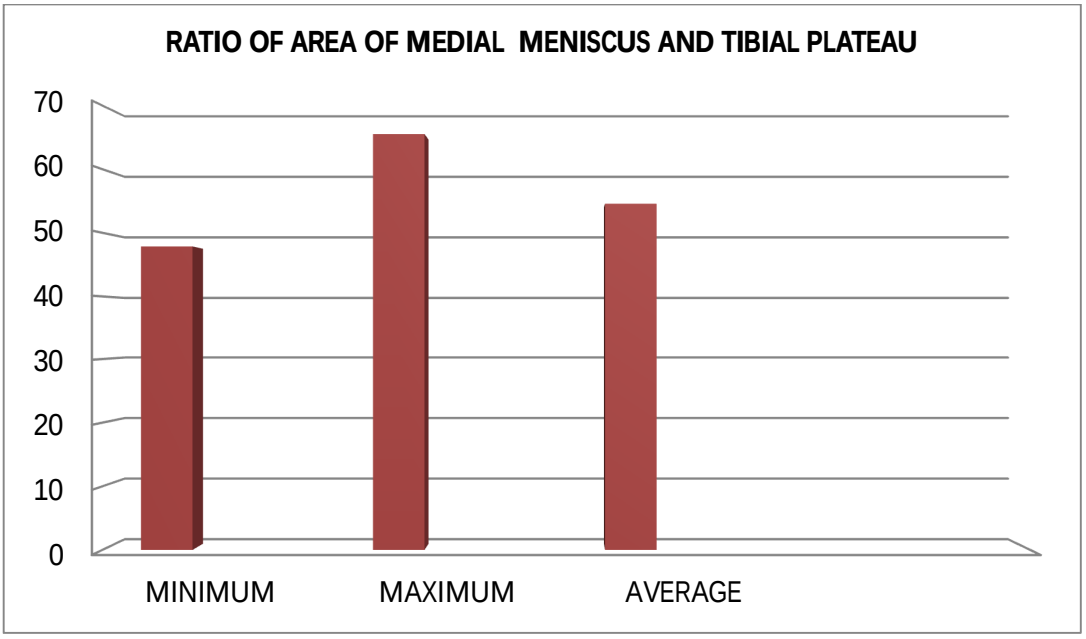
The mean value, standard deviation and range of the area of 50 medial meniscus were tabulated.

**TABLE NO. 16**

| STATISTICAL DATA | Ratio of surface area of medial meniscus /surface area of tibial plateau |
|---|---|
| Minimum | 47.85 |
| Maximum | 65.51 |
| Average | 54.56 |
| S.D | 4.08 |

The average ratio of area of medial meniscus/tibial plateau was 54.56 with standard deviation of 4.08. The maximum ratio of area of medial meniscus/tibial plateau was 65.51 and the minimum ratio of area of medial meniscus/tibial plateau was 47.85.

**CHART NO. 13**




The ratio of area of the medial meniscus/area of tibial plateau on left side and right side was assessed, tabulated and comparison was done.

**TABLE NO 17**

| **Ratio of area of the medial meniscus/area of tibial plateau Mean** | **Right** | **Left** | **p-value** |
|---|---|---|---|
| | 54.39 | 54.73 | ≥0.05 |

The mean of the right side was found to be 54.39 and the mean of the left side was found to be 54.73 and the p-value derived using t-test did not show any significance.

The ratio of area of the medial meniscus/area of tibial plateau seen in males and females were assessed, tabulated and comparison was made.

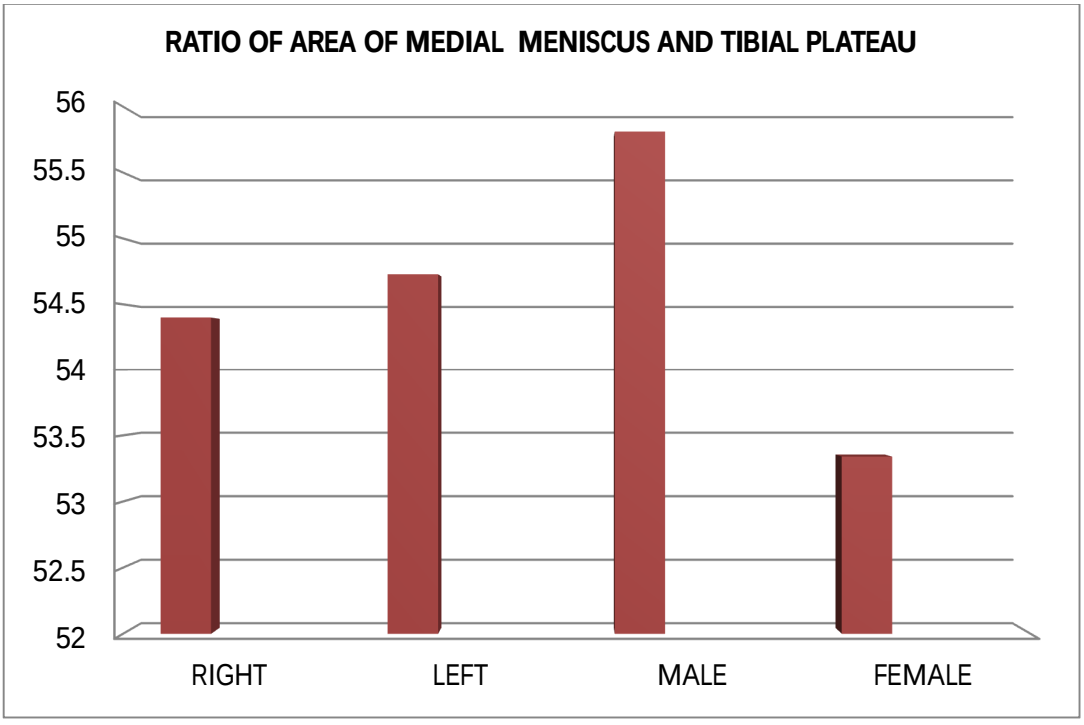
**TABLE NO. 18**

| Ratio of area of the medial meniscus/area of tibial plateau | Male | Female | p-value |
|---|---|---|---|
| | 55.81 | 53.34 | ≥0.05 |

The mean was found to be 55.81 in males and the mean was 53.34 in females. The p-value derived using t test did not show any significance.

The whole range of values is shown in the histogram.

**CHART NO. 14**



## 7. WEIGHT OF MEDIAL MENISCUS

Weight of the medial meniscus was taken using electronic weighing machine with the accuracy of milligrams.

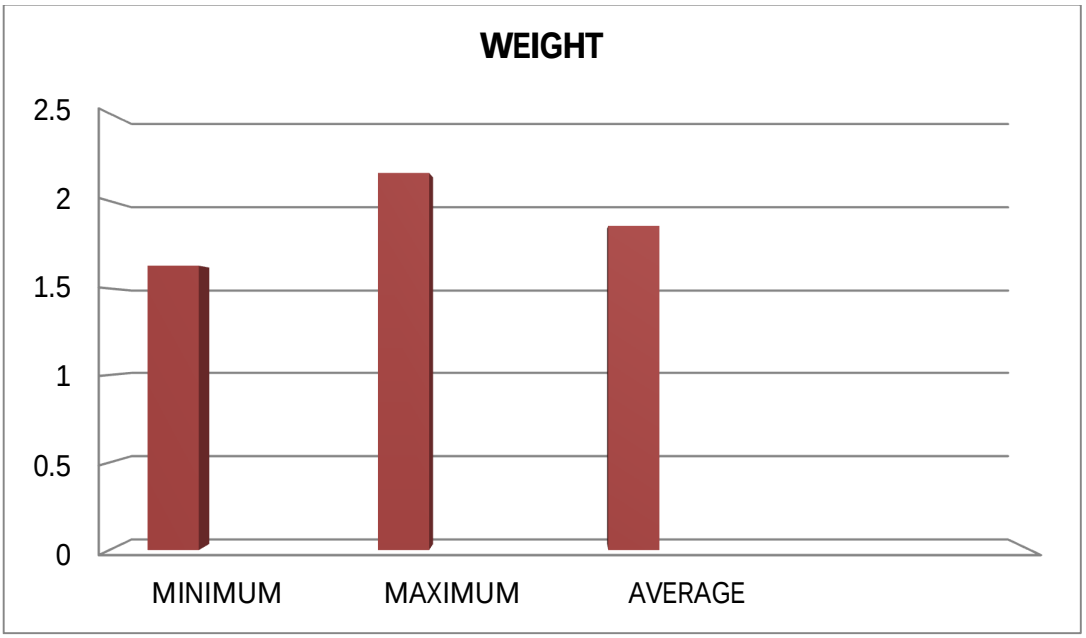
The mean value, standard deviation and range of the area of 50 medial menisci were tabulated.

**TABLE NO. 19**

| STATISTICAL DATA | Weight of medial meniscus |
|---|---|
| Minimum | 1.63g |
| Maximum | 2.16g |
| Average | 1.88g |
| S.D | 0.135 |

The average weight of the medial meniscus was 1.88g with a standard deviation of 0.135. The maximum weight of the medial meniscus was 2.16g and the minimum weight of medial meniscus was 1.63g.

**CHART NO. 15**




The weight of the medial meniscus seen on left and right sides were assessed, tabulated and comparison made.

**TABLE NO. 20**

| **Weight of the medial meniscus Mean(g)** | **Right** | **Left** | **p-value** |
|---|---|---|---|
| | 1.86g | 1.89g | ≥0.05 |

The mean was found to be 1.86g on the right side and the mean was found to be 1.89g on the left side and the p-value derived using t-test did not show any significance.

The weight of the medial meniscus seen in males and females were assessed, tabulated and comparison was made.

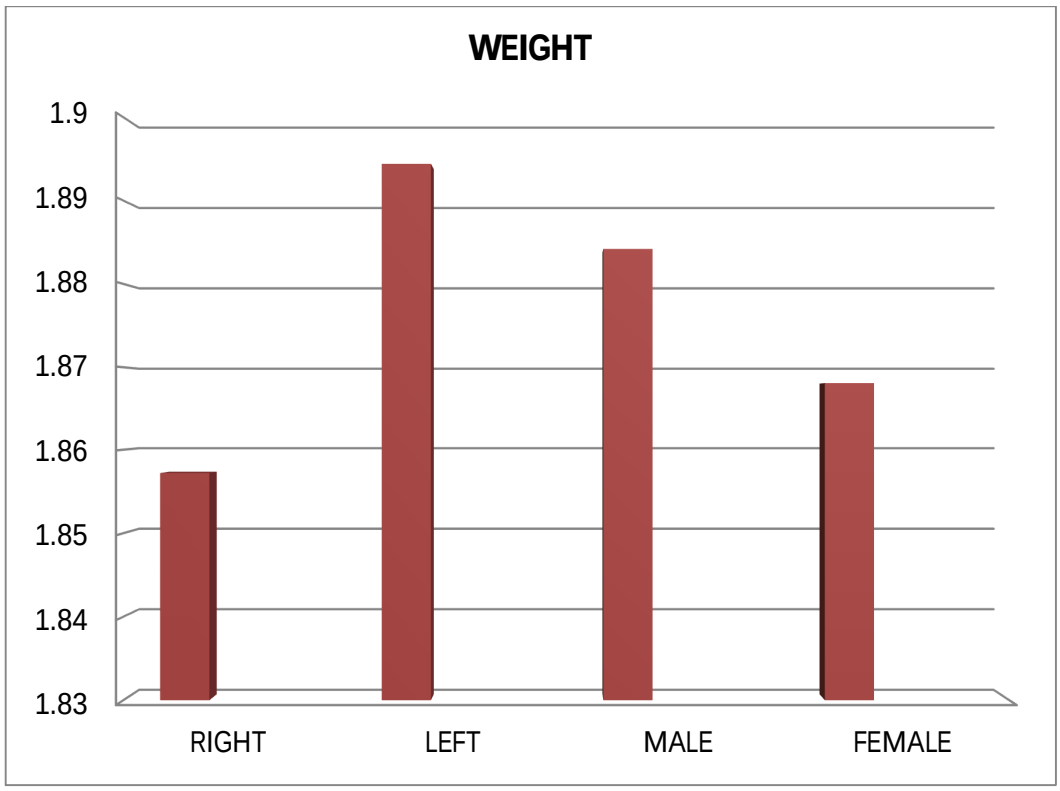
**TABLE NO. 21**

| Weight of the medial meniscus Mean(g) | male | female | p-value |
|---|---|---|---|
| | 1.88g | 1.87g | ≥0.05 |

The mean was found to be 1.88g in males and the mean was 1.87g in females. The p-value derived using t test did not show any significance.

The whole range of values is shown in the histogram.

**CHART NO. 16**



# *Discussion*

# DISCUSSION

Data related to the morphology of the menisci are scarce. The main objective of this study was to analyse the morphometric variations present in the human medial meniscus, thereby enriching the literature on this subject and correlating these variations with the type, location and possibility of lesion as shown in the literature review. The findings of the present study are compared with the findings of other similar studies conducted in other countries and different parts of India.

The morphological parameters of width of medial meniscus, thickness of medial meniscus, outer circumference of medial meniscus, inner circumference of medial meniscus, area of medial meniscus, ratio of area of medial meniscus/area of tibial plateau and weight of medial meniscus are discussed below

**1. WIDTH OF MEDIAL MENISCUS**

The comparison between various studies of width of the medial meniscus is given in the table below

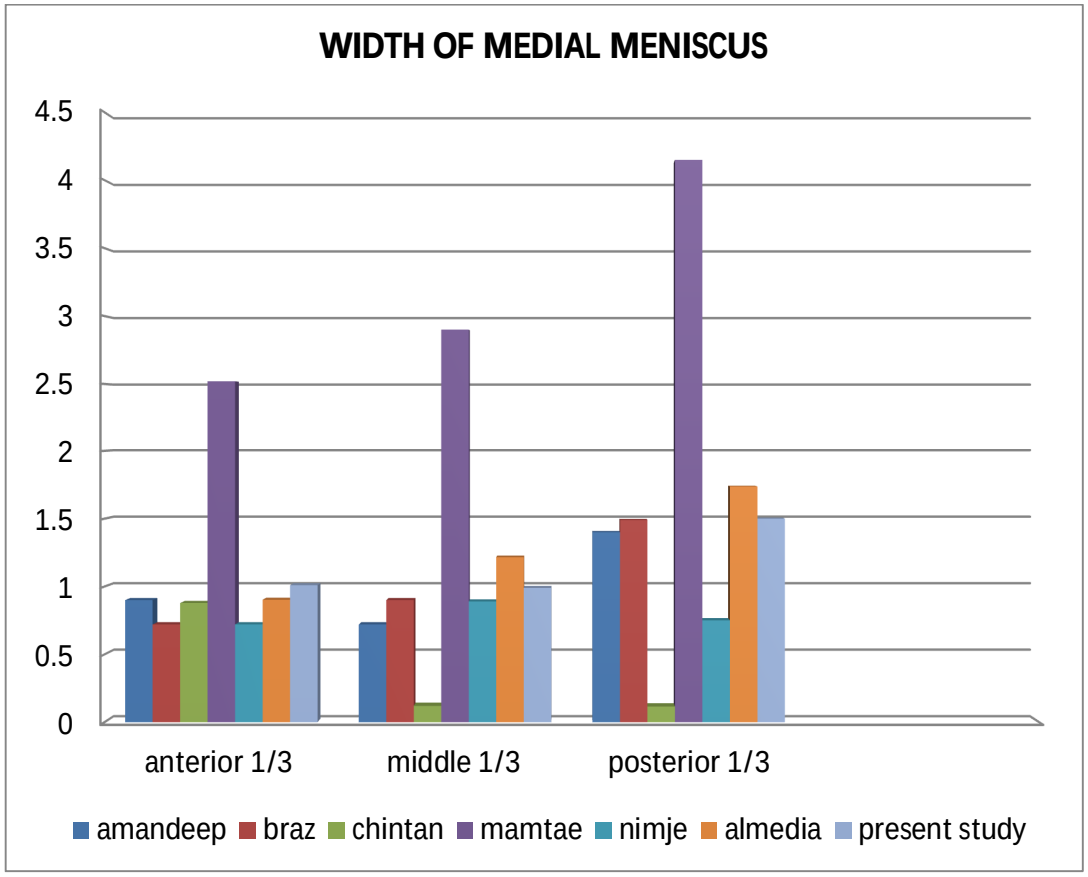
TABLE NO. 22

| SL NO | NAME OF THE STUDY | ANTERIOR 1/3 | MIDDLE 1/3 | POSTERIOR 1/3 |
|---|---|---|---|---|
| 1 | AMANDEEP KAUR ET AL (2013)[2] | 0.9cm[rt]<br>1.0cm[lt] | 1.0cm[rt]<br>1.1cm[lt] | 1.4cm[rt]<br>1.5cm[lt] |
| 2 | BRAZ & SILVA ET AL (2010)[4] | 0.72cm | 0.9cm | 1.49cm |
| 3 | CHINTAN ET AL (2014)[8] | 0.878 cm | 0.12cm | 0.115cm |
| 4 | MAMTAE ET AL (2013)[20] | 2.52cm[rt]<br>2.67 cm[lt] | 2.9cm[rt]<br>3.16cm[lt] | 4.15cm[rt]<br>4.85cm[lt] |
| 5 | NIMJE ET AL (2014)[5] | 0.72cm[rt]<br>0.74cm[lt] | 0.89cm[rt]<br>0.86cm[lt] | 0.75cm[rt]<br>0.67cm[lt] |
| 6 | ALMEDIA ET AL (2004)[1] | 0.902cm | 1.216cm | 1.737cm |
| 7 | **PRESENT STUDY** | 1.01cm | 0.99cm | 1.5cm |

As seen in the table above, the width of medial meniscus of anterior 1/3 of various studies falls in the range of 0.9cm to 1.2 cm and the present study also confirms this. The present study reported an average width of medial meniscus in the anterior 1/3 as 1.01cm. The width of the medial meniscus in the middle 1/3 in various studies falls in the range of 0.9cm to 1.2cm and the present study also

confirms this. The present study reported an average width of medial meniscus in the middle 1/3 as 0.99cm. The width of the medial meniscus of posterior 1/3 in various studies falls in between 1.15cm to 1.75cm and the present study also confirms this. The present study reported an average width of the medial meniscus in the posterior 1/3 as 1.5cm. Study conducted by Mamata et al differs in the values of width with other studies including the present study because it measures the width of the medial meniscus in a different way.

**CHART NO. 17**



## 2. THICKNESS OF MEDIAL MENISCUS

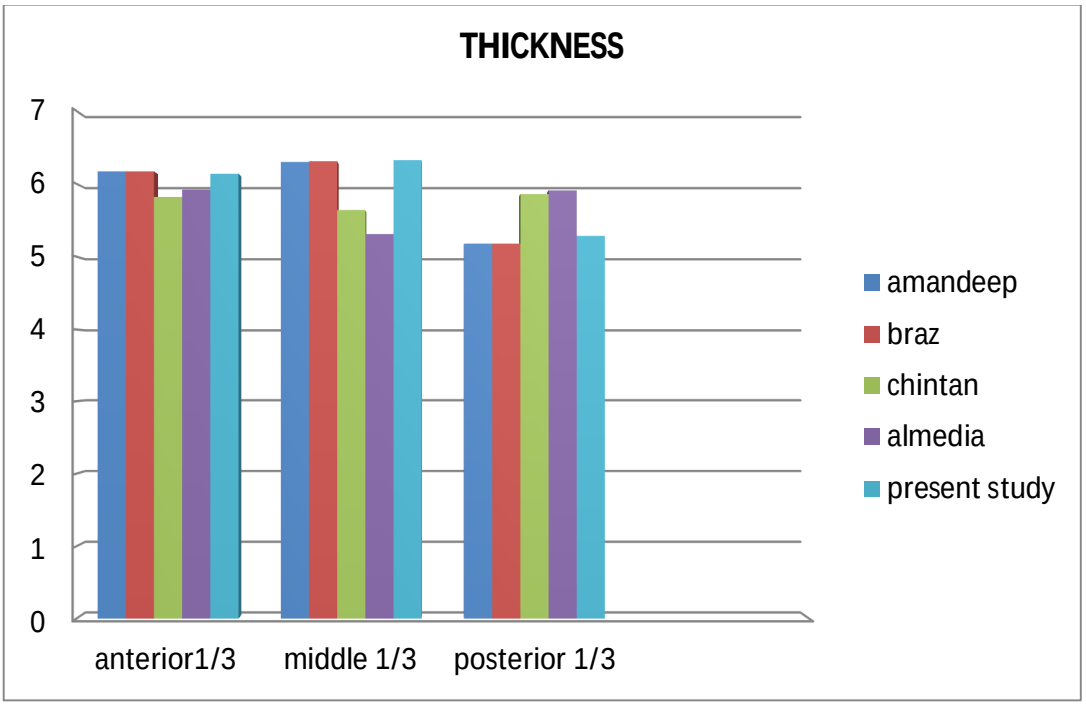
The comparison between various studies is given in the table below

**TABLE NO. 23**

| SL NO | NAME OF THE STUDY | ANTERIOR 1/3 | MIDDLE 1/3 | POSTERIOR 1/3 |
|---|---|---|---|---|
| 1 | AMANDEEP KAUR ET AL (2013)[2] | 6.17mm | 6.3mm | 5.18mm |
| 2 | BRAZ ET AL (2010)[4] | 6.17mm | 6.31mm | 5.18mm |
| 3 | CHINTAN ET AL (2014)[8] | 5.82mm | 5.64mm | 5.86mm |
| 4 | ALMEDIA ET AL (2004)[1] | 5.92mm | 5.31mm | 5.91mm |
| 5 | **PRESENT STUDY** | 6.14mm | 6.33mm | 5.29mm |

As seen in the table above, the thickness of medial meniscus in the anterior 1/3 falls in between 5.64mm to 6.17mm in various studies and the present study also confirms this. The present study reported an average thickness of medial meniscus in the anterior 1/3 as 6.14cm. The thickness of the medial meniscus in the middle 1/3 in various studies falls in between 5.31mm to 6.3mm and the present study also confirms this. The present study reported an average width of medial meniscus in the middle 1/3 as 6.33mm. The width of the medial meniscus in the posterior 1/3 in various studies falls in the range of 5.18mm and 5.91mm and the present study also confirms this. The present study reports an average width of the medial meniscus in the posterior 1/3 as 5.29mm.

**CHART NO. 18**




### 3. OUTER CIRCUMFERENCE OF MEDIAL MENISCUS

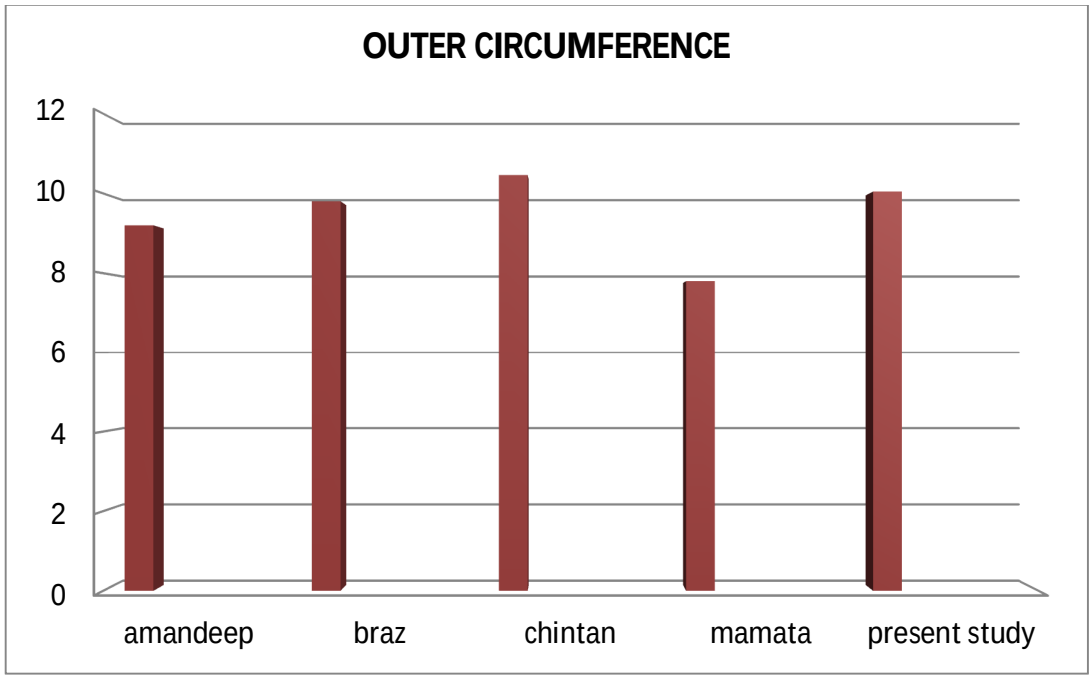
The comparison between various studies is given in the table below

**TABLE NO. 24**

| Sl no | STUDY | OUTER CIRCUMFERENCE OF MEDIAL MENISCUS |
|---|---|---|
| 1 | AMANDEEP KAUR ET AL (2013)[2] | 9.2cm[rt]<br>9.7cm[lt] |
| 2 | BRAZ ET AL (2010)[4] | 9.8 cm |
| 3 | CHINTAN ET AL (2014)[8] | 10.46cm |
| 4 | MAMATA ET AL (2013)[20] | 7.8cm[rt]<br>7.5cm[lt] |
| 7 | **PRESENT STUDY** | 10.05cm |

As seen in the table above, the length of the outer circumference of medial meniscus in various studies falls in between 9.5cm to 10.5 cm and the present study also confirms this. The present study reports the average length of the outer circumference of medial meniscus as 10.05cm.

**CHART NO. 19**



## 4. INNER CIRCUMFERENCE OF MEDIAL MENISCUS

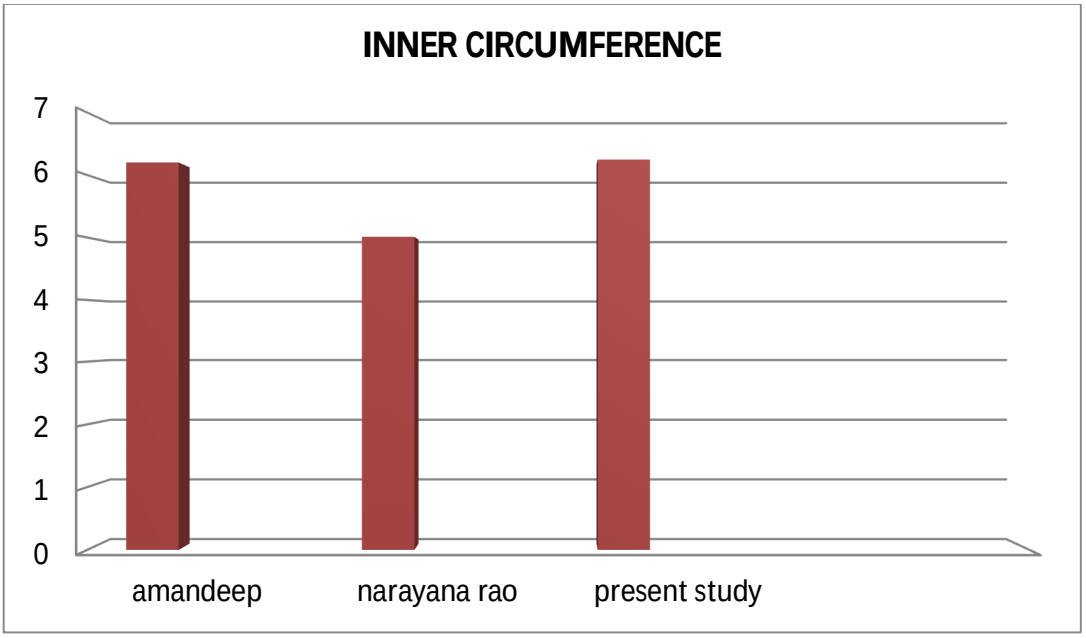
The comparison between various studies of length of inner circumference of the medial meniscus is given in the table below

**TABLE NO 25**

| Sl no | Name of the study | INNER CIRCUMFERENCE OF MEDIAL MENISCUS |
|---|---|---|
| 1 | AMANDEEP KAUR ET AL (2013)[2] | 6.2cm[rt]<br>6.4cm[lt] |
| 2 | NARAYANA RAO ET AL (2014)[26] | 5.01cm |
| 3 | **PRESENT STUDY** | 6.25cm |

As seen in the table above, the length of the inner circumference of medial meniscus in various studies falls in between 6.2cm and 6.4 cm and the present study also confirm this. The present study reports the average length of the inner circumference of medial meniscus as 6.25cm.

**CHART NO. 20**



## 5. AREA OF MEDIAL MENISCUS

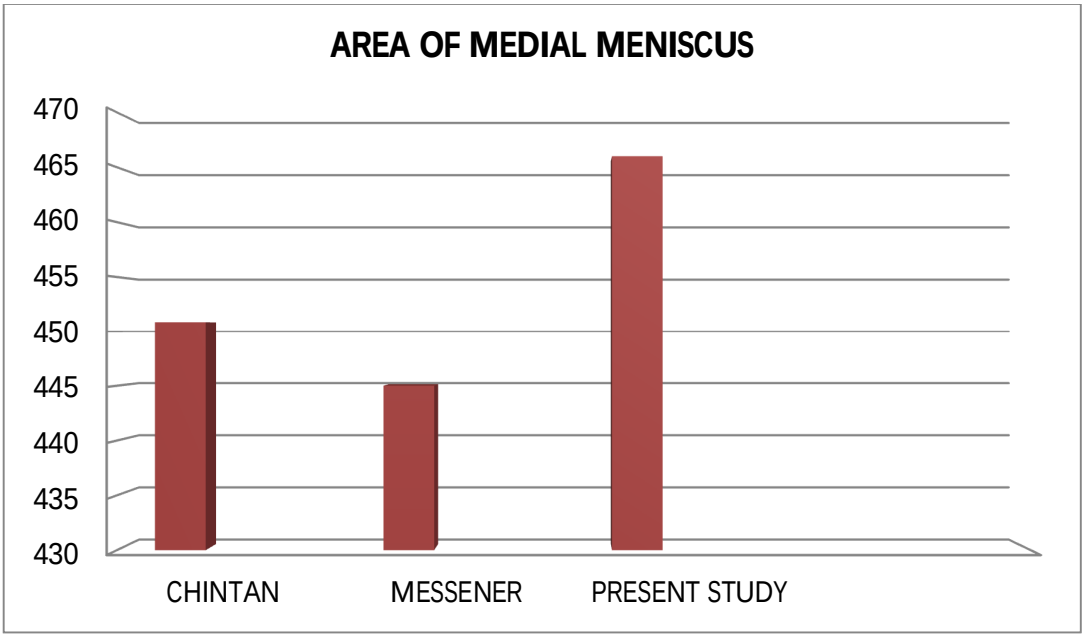
The comparison between various studies is given in the table below

**TABLE NO. 26**

| SL NO | NAME OF THE STUDY | AREA OF MEDIAL MENISCUS |
|---|---|---|
| 1 | CHINTAN ET AL (2014)[8] | 450.88mm$^2$ |
| 2 | MESSENER & GOA ET AL (1998)[22] | 445.0mm$^2$+93.3 |
| 3 | **PRESENT STUDY** | 466mm$^2$ |

As seen in the table above, the area of medial meniscus in various studies falls in between 450mm$^2$ and 470mm$^2$ the present study also confirm this. The present study reports the average area of medial meniscus as 466mm$^2$.

**CHART NO. 21**



## 6. RATIO OF AREA OF MEDIAL MENISCUS /AREA OF TIBIAL PLATEAU

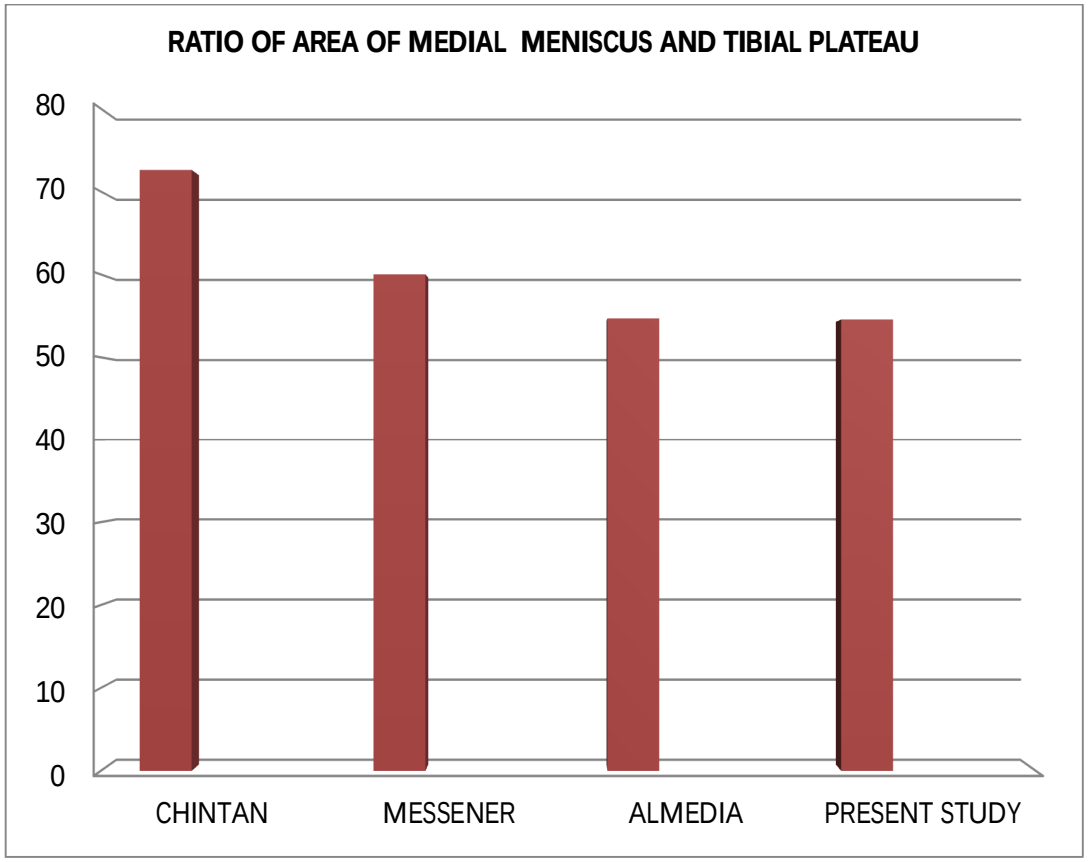
The comparison between various studies of ratio of area of the medial meniscus/area of tibia plateau is given in the table below

**TABLE NO 27**

| SL NO | NAME OF THE STUDY | RATIO OF AREA OF MEDIAL MENISCUS/AREA OF TIBIAL PLATEAU |
|---|---|---|
| 1 | CHINTAN ET AL (2014)[8] | 72.6 |
| 2 | MESSENGER & GOA ET AL (1998)[22] | 60 |
| 3 | ALMEDIA ET AL (2004)[1] | 54.70±7.32 |
| 5 | **PRESENT STUDY** | 54.56 |

As seen in the table above, the area of medial meniscus in various studies falls in between 50 and 70 and the present study also confirm this. The present study reports an average area of medial meniscus is 54.56.

**CHART NO. 22**


RATIO OF AREA OF MEDIAL MENISCUS AND TIBIAL PLATEAU
80
70
60
50
40
30
20
10
0
CHINTAN
MESSENER
ALMEDIA
PRESENT STUDY

## 7. WEIGHT OF MEDIAL MENISCUS

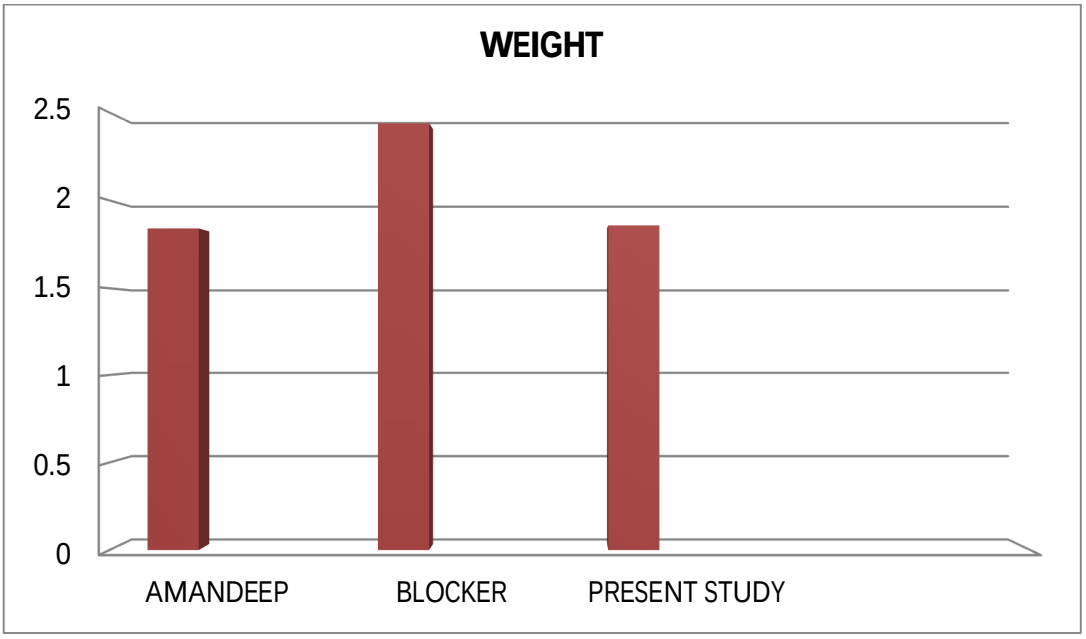
The comparison between various studies of weight of the medial meniscus is given in the table below

**TABLE NO. 28**

| SL NO | NAME OF THE STUDY | WEIGHT OF MEDIAL MENISCUS |
|---|---|---|
| 1 | AMANDEEP KAUR ET AL (2013)[2] | 1.84g[rt]<br>1.87g[lt] |
| 2 | BLOCKER ET AL (2012)[6] | 2.438ml |
| 3 | **PRESENT STUDY** | 1.86g |

As seen in the table above, the weight of medial meniscus in various studies in the range of 1.84g to1.88g and the present study also confirms this. The present study reports the average weight of medial meniscus 1.86g.

**CHART NO. 23**



# *Conclusion*

# CONCLUSION

The dimensions of medial meniscus are studied with respect to morphometric parameters like width, outer circumference and inner circumference, thickness, weight, area of medial meniscus, ratio of medial meniscus/area of tibial plateau and weight. The study was done by measuring 50 medial menisci retrieved from 25 embalmed cadavers. Of the 25 embalmed cadavers, 12 were males and 13 were females. The parameters were measured using measuring tape, threads, graph paper, digital vernier callipers, linear scale, pin, electronic weight scale and the results were compared with those of other studies. This study was a systematic effort to quantitatively and statistically characterize the morphometry of medial meniscus .

The average width of the medial meniscus in the anterior 1/3 is 1.01cm, middle 1/3 is 0.99cm and posterior 1/3 is 1.5cm. In the present study the posterior one-third was the widest part followed by anterior one-third and then the middle one-third. The posterior one-third of medial meniscus was the widest part and the anterior one- third was the narrowest part. The width of the medial meniscus can determine the kind of injury, possibility and also the location of injury. A narrow meniscus is less prone to rupture than a wider one, because of less action of femoral condyle. This is evident by the rarity of injuries of the anterior one- third of medial meniscus. The results are in unison with other studies and this should be kept in mind for manufacturing of prostheses.

The average thickness of medial meniscus in the anterior 1/3 is 6.14cm, middle 1/3 is 6.33cm and posterior 1/3 is 5.29cm.The middle one-third of medial meniscus is the thickest followed by the anterior one- third. The posterior third is the thinnest.

The average outer circumference of the medial meniscus in the present study is 10.05cm. There is no significant difference found between males and females and also between the right side and left side.

The average inner circumference of the medial meniscus in the present study is 6.25cm. There is no significant difference found between males and females and also between the right side and left side.

The average area of medial meniscus in the present study is 466mm$^2$. There is no significant difference when compared to other studies.

The average ratio of area of medial meniscus to area of tibia plateau is 54.56, the area of medial meniscus covers more than half of the medial tibial plateau. There is no significant difference when compared to other studies.

The average weight of medial meniscus in the present study is 1.84g. This parameter should be kept in mind for manufacturing prostheses.

The limitation of this study includes the simplistic technique of relying on linear measurement of a nonlinear structure. Hopefully this study will provide extra edge to the literature concerning the surgical procedures and arthroscopy of

the knee joint and will be of help to orthopaedic surgeons and morphologists. This cadaveric study is useful in such a way that actual dimensions of menisci are calculated instead of a radiological one. Being a cadaveric study, it approximates the living values but do not give the actual living values. Thus there is a scope of further research by doing CT and MRI of the knee joint and calculating the dimensions of menisci and thus correlating those with the living will give actual parameters for allografts to be transplanted in recipient knee.

In replacement surgeries, the graft failure due to mismatches can be avoided in general population, with good understanding of the morphometric features of meniscal morphometry. The present study provides a comprehensive set of quantitative measures of menisci which may be of help for designing artificial meniscal prostheses and for improvement of commonly used knee prostheses.

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# MASTER CHART

| | WIDTH [cm] | | | THICKNESS [mm] | | | outer circumference | inner circumference | area of medial meniscus | area of tibial plataeu | ratio | weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ANT 1/3 | MIDDLE 1/3 | POST 1/3 | ANT1/3 | MID 1/3 | POST1/3 | [cm] | [cm] | [mm2] | [mm2] | | [gms] |
| 1RM [RIGHT] | 0.95 | 1.02 | 1.45 | 6.03 | 6.35 | 5.24 | 9.96 | 6.16 | 454 | 693 | 65.51 | 1.89 |
| 2LM[LEFT] | 0.96 | 0.98 | 1.52 | 6.15 | 6.28 | 5.51 | 10.14 | 6.24 | 436 | 764 | 57.06 | 1.94 |
| 3RM | 1.04 | 0.99 | 1.49 | 5.96 | 6.33 | 5.42 | 10.05 | 6.06 | 482 | 751 | 64.18 | 2.16 |
| 4LM | 0.97 | 0.99 | 1.49 | 6.12 | 6.47 | 5.06 | 9.95 | 6.23 | 494 | 784 | 63.01 | 1.83 |
| 5RM | 0.99 | 0.97 | 1.53 | 6.31 | 6.29 | 5.24 | 9.85 | 6.44 | 464 | 796 | 58.29 | 1.64 |
| 6LM | 0.96 | 0.99 | 1.54 | 5.98 | 6.37 | 5.34 | 10.26 | 6.34 | 458 | 812 | 56.4 | 1.97 |
| 7RM | 1.02 | 0.96 | 1.48 | 6.02 | 6.24 | 5.18 | 10.04 | 6.41 | 494 | 824 | 59.95 | 1.66 |
| 8LM | 0.99 | 1 | 1.5 | 6.18 | 6.12 | 5.22 | 9.98 | 6.06 | 502 | 842 | 59.85 | 1.98 |
| 9RM | 0.99 | 1.04 | 1.49 | 6.13 | 6.38 | 5.19 | 9.91 | 6.13 | 424 | 886 | 47.85 | 2.09 |
| 10LM | 0.98 | 1.06 | 1.46 | 6.08 | 6.44 | 5.38 | 9.88 | 6.19 | 478 | 856 | 55.84 | 1.88 |
| 11RM | 0.97 | 0.98 | 1.54 | 5.96 | 6.36 | 5.14 | 10.04 | 6.28 | 446 | 872 | 51.14 | 1.76 |
| 12LM | 0.97 | 1 | 1.47 | 6.14 | 6.46 | 5.13 | 9.82 | 6.42 | 474 | 798 | 59.39 | 1.68 |
| 13RM | 0.96 | 0.99 | 1.53 | 6.21 | 6.49 | 5.44 | 9.94 | 6.32 | 412 | 786 | 52.41 | 1.94 |
| 14LM | 0.98 | 0.99 | 1.52 | 6.04 | 6.24 | 5.23 | 10.08 | 6.43 | 440 | 858 | 51.28 | 2.02 |
| 15RM | 1.02 | 1.01 | 1.53 | 6.08 | 6.18 | 5.28 | 10.02 | 6.14 | 486 | 912 | 53.28 | 1.78 |
| 16LM | 0.99 | 0.98 | 1.48 | 6.19 | 6.51 | 5.29 | 10.14 | 5.98 | 472 | 864 | 54.62 | 1.84 |
| 17RM | 0.98 | 0.96 | 1.49 | 6.11 | 6.29 | 5.14 | 10.21 | 6.34 | 468 | 904 | 51.76 | 1.92 |
| 18LM | 1.01 | 1.01 | 1.55 | 6.26 | 6.33 | 5.32 | 10.07 | 6.41 | 452 | 758 | 59.63 | 1.77 |
| 19RM | 0.97 | 1.02 | 1.5 | 6.05 | 6.54 | 5.18 | 9.93 | 6.39 | 498 | 946 | 52.64 | 1.96 |
| 20LM | 0.99 | 1.01 | 1.53 | 5.99 | 6.18 | 5.09 | 9.96 | 6.23 | 436 | 878 | 49.65 | 2.03 |
| 21RM | 0.98 | 0.96 | 1.49 | 5.96 | 6.35 | 5.38 | 10.12 | 6.25 | 476 | 924 | 51.51 | 1.76 |
| 22LM | 1.03 | 0.99 | 1.46 | 6.34 | 6.38 | 5.42 | 10.15 | 6.07 | 482 | 916 | 52.62 | 1.89 |
| 23RM | 0.97 | 0.97 | 1.52 | 6.26 | 6.24 | 5.32 | 10.07 | 6.09 | 508 | 898 | 56.57 | 1.75 |
| 24LM | 0.99 | 0.99 | 1.47 | 6.18 | 6.44 | 5.23 | 10.15 | 6.27 | 496 | 872 | 56.88 | 2.08 |
| 25RF[FEMALE | 0.98 | 0.98 | 1.49 | 6.05 | 6.11 | 5.28 | 10.23 | 6.39 | 432 | 884 | 48.86 | 1.63 |
| 26LF | 1.03 | 0.99 | 1.51 | 6.08 | 6.09 | 5.43 | 9.94 | 6.29 | 464 | 832 | 55.76 | 1.99 |
| 27RF | 0.98 | 1 | 1.53 | 6.16 | 6.43 | 5.28 | 9.89 | 6.21 | 488 | 924 | 52.81 | 1.92 |
| 28LF | 1.01 | 1.01 | 1.5 | 6.24 | 6.26 | 5.31 | 10.09 | 6.09 | 456 | 916 | 49.78 | 1.86 |
| 29RF | 0.99 | 1.02 | 1.48 | 6.18 | 6.49 | 5.15 | 10.25 | 6.11 | 442 | 848 | 52.12 | 2.14 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30LF | 0.97 | 0.99 | 1.46 | 6.29 | 6.42 | 5.23 | 9.95 | 6.16 | 478 | 868 | 55.06 | 1.79 |
| 31RF | 1.04 | 1.01 | 1.51 | 5.91 | 6.38 | 5.37 | 9.92 | 6.25 | 454 | 892 | 50.89 | 1.88 |
| 32LF | 0.99 | 0.98 | 1.55 | 6.07 | 6.16 | 5.34 | 10.03 | 6.32 | 428 | 874 | 48.97 | 1.73 |
| 33RF | 0.98 | 0.97 | 1.53 | 6.19 | 6.26 | 5.29 | 10.05 | 6.44 | 496 | 908 | 54.84 | 1.77 |
| 34LF | 0.99 | 0.99 | 1.46 | 6.11 | 6.37 | 5.43 | 10.21 | 6.31 | 468 | 854 | 54.8 | 1.83 |
| 35RF | 1.02 | 0.98 | 1.48 | 6.13 | 6.44 | 5.38 | 10.14 | 6.16 | 472 | 868 | 54.37 | 1.94 |
| 36LF | 0.96 | 0.99 | 1.5 | 6.28 | 6.31 | 5.36 | 9.86 | 6.14 | 476 | 918 | 51.85 | 2.07 |
| 37RF | 0.97 | 1 | 1.52 | 6.05 | 6.35 | 5.32 | 10.12 | 6.24 | 448 | 782 | 57.28 | 1.81 |
| 38LF | 0.99 | 1.01 | 1.49 | 6.33 | 6.08 | 5.44 | 10.28 | 6.38 | 492 | 894 | 55.03 | 1.85 |
| 39RF | 1.04 | 1.04 | 1.47 | 6.21 | 6.48 | 5.18 | 9.96 | 6.33 | 458 | 794 | 57.68 | 1.79 |
| 40LF | 0.96 | 0.96 | 1.53 | 6.12 | 6.13 | 5.26 | 10.13 | 6.14 | 462 | 814 | 56.75 | 1.87 |
| 41RF | 0.98 | 1.03 | 1.54 | 6.28 | 6.32 | 5.27 | 10.07 | 6.32 | 436 | 868 | 50.23 | 1.81 |
| 42LF | 1.03 | 1.01 | 1.48 | 6.21 | 6.24 | 5.34 | 10.14 | 6.11 | 498 | 928 | 53.66 | 1.91 |
| 43RF | 1.01 | 0.96 | 1.49 | 5.99 | 6.22 | 5.31 | 10.06 | 6.25 | 504 | 934 | 53.96 | 2.15 |
| 44LF | 0.99 | 0.98 | 1.5 | 6.27 | 6.43 | 5.17 | 10.21 | 6.34 | 476 | 814 | 58.47 | 1.99 |
| 45RF | 0.98 | 0.99 | 1.54 | 6.13 | 6.34 | 5.45 | 10.13 | 6.44 | 448 | 894 | 50.11 | 1.71 |
| 46LF | 0.96 | 0.99 | 1.54 | 6.18 | 6.11 | 5.29 | 9.93 | 6.31 | 454 | 902 | 50.33 | 1.79 |
| 47RF | 1.02 | 1.01 | 1.47 | 6.17 | 6.38 | 5.44 | 9.95 | 6.04 | 460 | 786 | 58.52 | 1.69 |
| 48LF | 0.99 | 0.98 | 1.53 | 6.12 | 6.25 | 5.13 | 10.05 | 6.19 | 426 | 878 | 48.51 | 2.01 |
| 49RF | 1 | 0.96 | 1.49 | 6.32 | 6.53 | 5.19 | 10.23 | 6.21 | 494 | 928 | 53.23 | 1.88 |
| 50LF | 0.99 | 0.98 | 1.51 | 6.09 | 6.44 | 5.37 | 9.89 | 6.33 | 458 | 864 | 53 | 1.76 |